



**OTMC**  
Conference **2019**

&

**Zagreb**  
2019

**IPMA**®  
**7<sup>th</sup> Research**  
Conference

## CONFERENCE PROCEEDINGS

# Trust in Major & Mega Projects

14<sup>th</sup> Organization, Technology & Management in Construction Conference  
& 7<sup>th</sup> IPMA Research Conference, The Westin Zagreb, September 4-7, 2019

**Croatian Association for Construction Management**

**University of Zagreb, Faculty of Civil Engineering**

**14<sup>TH</sup> INTERNATIONAL CONFERENCE  
ORGANIZATION, TECHNOLOGY AND  
MANAGEMENT IN CONSTRUCTION**

**AND**

**7<sup>TH</sup> INTERNATIONAL PROJECT  
MANAGEMENT ASSOCIATION  
RESEARCH CONFERENCE**

**CONFERENCE PROCEEDINGS**

**Zagreb, September 04 - 07, 2019  
Zagreb, Croatia**



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Zagreb  
2019

IPMA®  
7<sup>th</sup> Research  
Conference

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The 14th International Conference on Organization, Technology and Management in Construction 2019 and 7<sup>th</sup> IPMA Research Conference 2019 have been financially supported by the Ministry of Science and Education of the Republic of Croatia.

## Foreword

Dear Colleagues, dear Friends,

On behalf of the Organizing Committee, it is my great pleasure to welcome you to the 14<sup>th</sup> OTMC, International Conference and 7<sup>th</sup> IPMA Research Conference. This time we meet again to share new knowledge in the field of organisation, technology and management in construction, but also on actual topics in project management.

The five keynote lectures, given by distinguished authors, will lead us into actualities from the field of the conference. During the parallel sessions we will have opportunity to hear and discuss presentations of 81 peer reviewed papers authored by more than 200 researchers from 33 countries.

The conference will also provide numerous academic and other related activities. We need to specially mention workshop on publishing in high impact factor journals, which is designed to help young researchers in dissemination of their results. Also, we highlight IPMA Mega Project Special Interest Group meeting with participation of top-class experts and open for all participants.

Beside scientific and academic content, the conference will host the discussion panel on good practices in Croatian Construction Project Management Practice with participation of eminent professionals and large clients.

We would like to express our thanks to the patrons of the conference. Furthermore, we thank to the sponsors and all of the partners for their generous support for making this conference successful.

We wish you all productive participation at the Conference, establishing many new contacts and having a pleasant stay in Zagreb and Croatia.

Yours Sincerely,



*Prof. Ivica Završki, Ph.D.*

*Chair of the Organizing Committee*

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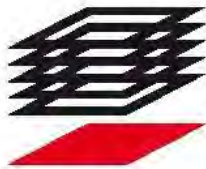
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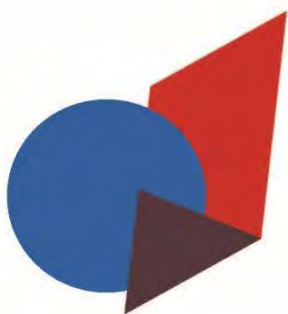
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# **Keynote Lectures**

# Creating Trust in Mega Projects – Experiences from Two Railway Mega Projects in Switzerland.

Peter Jedelhauser

*Swiss Federal Railways, Director of the programme “Léman 2030”, Switzerland*

---

## **Abstract:**

According to SBB predictions, between 2010 and 2030, the program will double transport capacity from 50,000 to 100,000 passengers per day.

This 4 billion CHF megaproject is designed to substantially improve the offer, timetables and capacity of rail transport (passenger and freight) along the Lausanne – Geneva corridor. It includes, among others, the implementation of new rail traffic regimes in the Lausanne area, the complete modernization / extension of the Lausanne and Renens railway stations as well as the construction of a new underground station in Geneva.

# Building Customer Trust in Mega Projects – experiences from 5G projects at HUAWEI

Johnson Yi

*HUAWEI, Director of Project Management Center of Excellence*

---

## **Abstract:**

HUAWEI is the world's largest supplier of telecommunications network equipment and second-biggest maker of smartphones. HUAWEI had won more than 25 commercial 5G contracts and shipped more than 10,000 base stations for 5G. HUAWEI is winning the trust of more and more customers through its 5G projects.



# Opportunities of Digital Transformation for Better Project Management

Soonwook Kwon

*Sungkyunkwan University, South Korea*

---

## **Abstract:**

As semiconductor and display fabrication (FAB) projects are becoming larger, more complex, and more diversified. Conversion of current factories into smart factories using ICT (Information & Communication Technology) has been a recent trend in the manufacturing industry. To create a smart factory, shifting of methods and processes to various ICT applications are required.

Amongst these ICT systems of Smart Factory, Digital Transformation is an essential method that can manage the status of equipment and production lines based on digital models that can interact with the physical environment of the real world. In this presentation, it is proposed a strategy for utilizing information generated at the construction stage of FAB facilities for Digital Transformation, and a strategical planning for prototyping of innovative FAB lifecycle management process. The expected contribution of the presentation will be able to simulate, predict and control data for lifecycle management of FAB facilities with Digital Transformation method.

# Project Finance and Public-Private Partnership (P3) for Transportation Infrastructure Mega Projects in the United States: A Critical Assessment of Barriers and Enabling Mechanisms

Baabak Ashuri

*School of Building Construction and the School of Civil & Environmental Engineering at Georgia Tech, USA*

---

## **Abstract:**

State Departments of Transportation (state DOTs) in the United States seek private investments to leverage their shrinking financial resources and fulfill their growing funding shortfalls. The private sector can provide innovative ideas through establishing effective public-private partnership (P3) contracts for design, construction, and operations of major transportation infrastructure assets in the U.S. Decisions to involve the private sector in financing, developing, and operating transportation mega projects vary from state to state in several aspects. This research talk aims to capture the underpinnings of P3 and private financing as utilized by state DOTs in development of transportation mega projects.

# Planning and Scheduling Mega Projects: A Case Study of a Nuclear Power Plant

Miklos Hajdu

*Budapest University of Technology*

---

## **Abstract:**

According to one of the definitions among many others for mega projects „Megaprojects are temporary endeavors (i.e. projects) characterized by: large investment commitment, vast complexity (especially in organizational terms), and long-lasting impact on the economy, the environment, and society”. Nuclear power plants, by all means, can be considered as mega projects. Mega projects due to their complexities have a long record of poor delivery and nuclear power plants are no exceptions. Consequences of poor delivery can have fatal and long-lasting consequences for millions of lives therefore all the steps of the project – including construction – must be carefully designed, executed and controlled. Construction of nuclear power plants therefore are helped/controlled by international agencies by collecting and evaluating events in other nuclear facilities, publishing safety guides and technical report, sharing best practices, etc. in order to ensure safety above all. These safety guides are more about the expectations and less about the „hows”. This paper presents the work that aims to give clear directives about planning/scheduling and monitoring requirements of the construction of nuclear power plants by avoiding being too specific but yet direct enough to ensure maximal expectations regarding general safety.

# Invited lecture: The Future of Project Management in Rurality and Trust in Sustainable Food Production in 2050

Jesús Martínez-Almela<sup>1</sup>

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## **Abstract:**

Rural World, in each country and region, hold its own and legitimate rights, needs, expectations and life projects toward its present and future. To be Smart implies the justice, the intelligence and ethic awareness to recognize it. However, have we really a ‘competent system conceived to promote that? What should be, indeed, the scope of Change and Transformation in rural development projects? The biggest challenge faced by our current technologies is not how to continue their linear –and often blind– march towards greater “inward” design sophistication, but the greatest challenge will be to know how to lead this technologies “outwards” that is, to aim them towards the creation and promotion of knowledge, expertise and even sensitivity in order to contextualize them in a timely, systematic and progressive manner within the scenarios of objectively important human needs –properly understood and diagnosed. Technology does not really depend on its advanced design-function but in our competences to implement, it is a crucial step to be able to learn, conceive, design and conduct every technical-instrumental effort into the holistic view of human change and transformation. Smart Project Management focus as alternative initiative capable of reconciling the potentials of technological innovation with economic-social integration strategies for the improvement of quality of life in rural populations, its actual participation and capabilities development, to fight against poverty and the correlated environmental damage (indeed, the most intelligent “device” in rural development). This uses various approaches, methods and technologies, which, nevertheless, will continue to represent the challenge of constituting a specialized and flexible arsenal. It should be capable of being shared and powered for the benefit of management, formulation and evaluation of rural environment projects. These precedents are essential for progressing towards the generation of international standards specializing in the management, formulation and evaluation of rural development projects.

*Keywords: smart, rural, international, standard, trust, project*

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# **Construction and Project Management Issues**

# Contribution to Increasing the Cost Efficiency in the Exploitation Phase of Public Education Facilities

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## Abstract:

The paper provides an overview of the public educational facilities cost management in the territory of the Republic of Croatia when it comes to facility maintenance and energy consumption in the exploitation phase. Cost rationalization and appropriate measures regarding facilities maintenance and energy consumption costs are in the focus of research interest. Previous studies have shown that the costs of facilities maintenance during its lifecycle are multiple in relation to construction costs, it is, therefore, important to influence the reduction of these costs, even in the planning and design phase, thinking of the consequences in the exploitation phase. As the educational facilities cost management cover the public sector, reducing these costs and increasing their efficiency is of wider social interest. In this paper, by reviewing the literature and analyzing the financial statements of several facilities, it has been established that educational facilities cost management in the mentioned segments, is not efficient enough, therefore, it is necessary to establish and carry research to provide concrete and effective measures to rationalize these segments. A research proposal that would provide such measures is given at the end of the work.

**Keywords:** *public educational facilities; facility management cost; rationalization measures; cost efficiency*

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## 1. Introduction

Until a few decades ago all the attention of investors, architects and contractors has been focused on reducing construction costs, and a few project participants paid attention to reducing costs during the exploitation phase of the facility, i.e. the costs of maintenance and use of facilities (Marenjak et al., 2002). Studies have shown that the cost of using and maintaining during the lifecycle of the building is multiple compared to construction costs, hence the importance of planning the maintenance and use of buildings is unquestionable. Planning enables more rational management of existing buildings as well as a more rational approach to designing new buildings with the possibility of reducing property costs in the service life of buildings, i.e. the need for systematic prediction and spending of resources for maintenance and use of buildings. Some authors (Krstić, 2011; Alqahtani and Whyte, 2016) point out that the area of use and maintenance of buildings is still in the initial stage of development and is not supported by an appropriate knowledge base, development is not supported either on the practical side. It is clear that more attention needs to be paid to planning and reducing the cost of use and maintenance of buildings, particularly to buildings where costs in the exploitation phase are covered by the public sector. Particularly great disadvantages have been observed in educational buildings (State Audit Office, 2018; [1]) which are characterized by significant

costs, both in the construction phase and in the stage of exploitation of the facilities. Reducing costs during the exploitation phase of educational buildings is of wider social interest. Into account should also be taken the special features of public facilities in relation to private sector facilities, such as: zero discount rate reflecting the particularity of the public sector structure that is viewed as both social and non-capital projects, longevity of projects, little or no revenue over the life span (Krstić, 2011).

Some literature (State Audit Office, 2018; [1]) and practical experience have shown that at the level of the Republic of Croatia, besides uneven standards and quality, there is also unsatisfactory care about maintenance and management of school facilities (elementary and high schools). Irrational energy (sources) consumption has also been established.

Considering the aforementioned problem of reduced cost efficiency during the phase of maintenance and energy consumption, the aim of this paper is to evaluate precisely those aspects in Croatian schools, to determine are the prescribed standards and quality in this area achieved, to determine whether cost efficiency in the exploitation phase is really reduced and to suggest research that would provide the most effective measures to increase and optimize these costs.

With the Introduction the work is organized in the following way: the second chapter points to the importance of educational facilities in human society; the third section presents the current knowledge of the topic being discussed and the review of the status of elementary and high schools in the Republic of Croatia; chapter 4 deals with the analysis of collected financial data for the exploitation phase of selected schools, data are processed and interpreted; the last chapter is the closing chapter in which a proposal for a future study and measures that should be taken to increase the efficiency of educational facilities during the exploitation phase is given.

## **2. The Importance of Educational Infrastructure Facilities**

Educational buildings are important for transfer knowledge in everyday life (Ropi and Tabassi, 2014). They receive inputs from the outside environment in the form of human and material resources, handle them and release into the society as finished products and services. They exist to serve the socio-economic and political needs of a society that is constantly changing; therefore, they are in constant interaction with their external environment (Asiabaka, 2008). According to Palis and Misnan (2018), educational buildings act as an envelope, which buffers external environments creating an internal atmosphere, which supports domestic needs. Buildings, classrooms, laboratories, and equipment - educational infrastructure - are key elements of learning environments in schools and at universities [2].

Educational facilities must meet the minimum infrastructure, financial and human resources requirements for the achievement and development of activities and the same conditions for uniform development of education (State Audit Office, 2018). There is strong evidence that high-quality infrastructure facilitates better teaching, improves student outcomes, and reduces school leaving rates, among other benefits [2].

The maintenance and operating of educational buildings, serving staff and students, requires significant attention because effective maintenance and operating, protect capital

investment, ensure child health and safety, and supports educational outcomes (Ropi and Tabassi, 2014). Xaba (2012) claimed that well maintained and managed, educational facilities provide conducive environments that translate into quality education. Well-maintained and utilized educational facilities can realise substantial efficiency gains, also deepen national and sector values of school community relationships and community ownership of schools (Xaba, 2012). A basic minimum package of educational infrastructure, which is accessible, durable, functional, safe, hygienic and easily maintained, needs to be part of any strategy to meet every education development strategy.

### **3. State of the art**

Educational facilities cover a wide range, from kindergartens, small schools to major universities. Within this range, it is most difficult to public bodies to manage elementary and high schools due to their large number and scattered locations (Ahluwalia, 2008). Managing and maintaining school buildings in good condition is very important because its conditions directly affect the well-being and achievement of students (Akasah et al., 2010). There are numerous examples in the literature that show that students learn better in an environment that is comfortable, safe, and without conditions hazardous to health (Ahluwalia, 2008).

The life-cycle of the building could be compared to the life span of man, where the passage of time causes aging, deterioration, and damage, at the same time, the most important factor in maintaining the function and value of the building depends on the quality of construction, long term maintenance and maintenance management (Chang Sian et al., 2010). After decades of use, school buildings often experience deterioration of critical building components, such as structural system, roofing, building envelope, floors, etc. (Alshamrani, 2012). Other consequences of poor maintenance include an unsafe and unhealthy environment, lower quality of teaching, lower quality of life, vandalism (Ahluwalia, 2008). Minimally or negligent maintenance can cause early fail while proper maintenance will allow for long service life. A school facility for many years should not fail if there is continuous proper maintenance and dedication, diligence and professionalism in work and management (Alshamrani, 2012).

The poor state of school facilities, together with the backlogs of costs, makes managing the maintenance of educational buildings a very complex and challenging task (Ahluwalia, 2008). Overestimating or underestimating maintenance costs could have a negative impact on decision making on the maintenance task hierarchy, as well as on the effective use of maintenance budgets. Although there are different approaches to cost estimation, each method has its own limitation given the different types of maintenance work. The overall maintenance plan must include information on the allocation and prioritization of the required resources for maintenance operations (Li et al., 2018). In order to optimize the available resources, it is important to undertake good asset management practice and to make the best use of funds (Ahluwalia, 2008). Many studies in the world indicate that school facilities are not well-maintained (Akasah et al., 2010). Factors contributing to the maintenance "gap" include planning failures, inadequate resources, inadequate understanding, poor management of funds, poor estate management and provision, which does not correspond to educational needs (Hinnum, 1999).



Poor maintenance also increases current costs such as energy costs. Part of the energy is wasted due to the habits of users and equipment conditions and here is a great potential for energy savings (Roslizar et al., 2014). The cost of energy, for example, can account for more than one-third of the cost of the facility, so reducing energy consumption not only saves money but also reduces carbon dioxide emissions and other forms of pollution (Ahluwalia, 2008). Energy is controlled cost that can be reduced by the right type of investment and management. Studies estimate that almost one-third of the energy consumed in an average school is lost. The least energy-efficient school use nearly four times more energy per square meter than the highest energy-efficient school. Schools that reduce their energy bills can channel that money to their primary mission, which is education (Chang Sian et al., 2010).

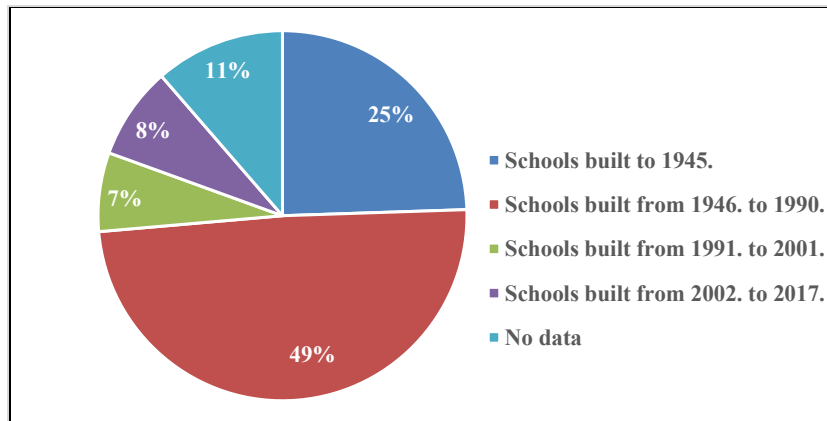
By reducing the number of new construction projects, focus on existing buildings is a key factor of energy costs in schools. By implementing a school's energy efficiency strategy, significant savings in energy costs, as well as the lifetime and improvement of the overall physical condition of school facilities can be achieved. Most energy efficiency measures should be carried out on existing facilities to achieve significant energy and cost savings, but even the most energy-efficient new schools have to implement good management practices during exploitation to avoid energy consumption and unnecessary costs (U.S. Department of Energy, 2009). Improving energy efficiency in schools sometimes does not have to cost millions. Schools can reduce their energy costs by 5 to 20% through efficient management in the exploitation phase, and thus energy costs have the potential to be the main source of cost savings. This is true regardless of the age of the school building (U.S. Department of Energy, 2008; Roslizar et al., 2014).

During new buildings or major renovations, schools and public bodies that finance them need to consider the issue of maintenance and energy consumption already in the design phase. Some research has shown that in the design phase it can affect 70% to 80% of maintenance and usage costs as significant life-cycle costs for future buildings (Krstić, 2011; Krstić and Marenjak, 2012). Even the slightest negligence during the design phase can result in difficulties in the exploitation phase and thus affect the whole life cost of the building. Therefore, it is very important that the earlier decisions and initiatives are taken into consideration during the design phase in order to ensure the proposed building design is maintenance-friendly and sustainable throughout the whole life-cycle of a building (Ali et al., 2013).

Educational institutions are essential for the development of people and, ultimately, for the prosperity of the state economy. By increasing the cost of building and doing business, schools need to be economically and efficiently built so that the building serves customers and is at the same time a wise investment for the community (New Hampshire Department of Education Concord, 2006). A key consideration for construction professionals is to achieve the goal of economic efficiency, protection and renewal of ecological systems. More than ever, there is public awareness of the impact of the building on the health and well-being of people because they spend most of their time in them. People are beginning to strive to live and work in comfortable, healthy buildings and buildings along with energy saving measures (Olaniyi, 2017).

### 3.1. The state of educational facilities in the Republic of Croatia

In the last revision report from 2018 (State Audit Office, 2018) on Croatian schools and education, it has been established that at the level of the Republic of Croatia there are 2521 school buildings, of which 2159 are elementary (911 main, 1248 regional) and 362 are high schools. Most of these school buildings are older than 30, and 25% of all schools in the Republic of Croatia are older than 70. Figure 1 shows the share of the number of buildings of elementary schools, and high schools according to the years of construction.



**Figure 1. Age of elementary and high schools in the Republic of Croatia (State Audit Office, 2018)**

The Audit Office concluded that such a network of schools was not optimal. Also, there are no data on the state and equipment of the schools. It is also concerned that asbestos was found in as many as 120 schools, and for 407 schools there is no data on embedded health and environmentally unacceptable materials. This is primarily the responsibility of municipalities, cities and counties in whose schools are the competence (State Audit Office, 2018; [1]).

“The Framework program for the construction, extension and renovation of public buildings according to the public-private partnership form of contract” points out that at the level of the Republic of Croatia there is a great need for investing in public infrastructure, including schools. The current ways of investing in public buildings have resulted in uneven standards, uneven quality and cost of construction and investment realization models in these areas do not meet both the pace of investment realization and the quality and cost of projects, which resulted in exceeding the planned funds and time and the deviations in the realization of public buildings. As extremely unsatisfactory, project management has been shown in all sectors as well as care about maintenance and management of built public buildings ([1]; Tijanić et al., 2019). In order to solve this problem, the Framework Program proposes that the needs for construction, extension and reconstruction of public facilities be solved by applying public-private partnerships. A positive example of public-private partnership implementation for reconstruction and construction of school buildings is visible in the Varaždin County. The aim of the Framework Program is, beside the construction, extension and reconstruction of public buildings, to ensure quality conditions that the constructed buildings meet the prescribed standards and quality during tens of years of use and that later generations of users of these buildings have the same conditions that existed in the first years after the construction of these buildings [1].

A number of schools in Croatia have also been renovated through projects financed from European funds. The grant funds of the European Regional Development Fund are secured based on a call from the Ministry of Construction and Physical Planning for Energy Renewal of Buildings and the Use of Renewable Energy Sources in Public Institutions Performing Education [3]. The purpose of this renewal is to ensure better working conditions in schools, but also to achieve significant financial savings by increasing energy efficiency and reducing energy consumption [4]. Due to high energy consumption in school buildings, taking measures and realizing energy efficiency in such areas today become the priorities of modern architecture and energy, but also lifestyles and sustainable development in general [5].

Despite positive examples, according to the Croatian Minister of Regional Development and Funds of the European Union, the state of the school remains critical throughout Croatia, and the biggest problems are in underdeveloped areas due to the lack of financial resources [6]. The poor state of schools is also witnessed by newspaper articles that almost daily point to the disrepair of school buildings (Figure 2).



**Figure 2. The neglected state of particular schools in the Republic of Croatia [7, 8, 9, 10]**

Literature (State Audit Office, 2018; [1]) among others points out the following shortcomings of the buildings of the Croatian education system:

- uneven standards and quality of construction,
- unsatisfactory care about maintenance and management,
- insufficient quality and rational management of energy consumption,
- prior to making a decision on investments, the costs of use and maintenance and sources of funding are not estimated,

- the existing planning system does not provide sufficient quality monitoring to achieve the desired results and effects...

In the report on the conducted audit of the efficiency of capital investments in elementary and high schools in the Republic of Croatia (State Audit Office, 2018) it is recommended to:

- estimate the costs of use and maintenance prior to making a decision on investments, in order to avoid deviations, take measures and achieve the planned values,
- make an analysis of investment outcomes in relation to planned use and maintenance costs,
- take measures in cases where the investment outcome indicators deviate from the planned goals, i.e. the purpose of the investment is not achieved.

#### 4. Analysis of financial statements

In order to analyze the situation of Croatian schools in the exploitation phase, in terms of current and investment maintenance and energy consumption, relevant data were collected.

Sixteen educational facilities were analyzed in four Croatian cities: Zagreb, Rijeka, Split and Osijek. The analysis covers only finances from 2018 because of the availability of data. The buildings were chosen by random selection and based on the existence of a 2018 financial plan and financial statement at the end of the same year. The mentioned financial plan and report are public documents that most schools publish on their web site.

The financial plan is drawn up for a three-year period. The planned costs in this paper are taken from the financial plans where the planned costs for 2018 and the projections are planned for 2019 and 2020. Mostly, for all three years, the same cost values are planned based on the realized costs from previous periods. The financial statement includes all revenues and expenditures of the observed public property from 1 January to 31 December of the analyzed year and a comparison with the previous year. Each item of the financial report at the level of the Republic of Croatia is marked with the same mark or code.

The cost data analyzed in this paper are presented in Table 1, and their marks from financial documents are also written.

**Table 1. Analyzed cost data for schools**

Code	Cost data
3	Operating expenses
3223	Energy
3224 + 3232	Materials, parts and services for current and investment maintenance

For each of the four cities, two elementary and two high schools are selected, which means that at the level of the Republic of Croatia a total of eight high schools and eight elementary schools have been analyzed. With the financial data for each school, the average number of

students from each school was collected. This data for each school can be downloaded individually from the application "ŠeR - Školski e-Rudnik". Also, data were collected on the year of construction of each school taken from state audits for capital investments in elementary and high schools by counties (State Audit Office, 2018).

Collected financial data are presented in Table 2 where the cost value per student is shown. Information on the names of observed objects is available from the authors of this paper.

**Table 2. Collected school data**

Num.	2018 (kn)	High schools			Elementary schools		
		3	3223	3224+3232	3	3223	3224+3232
Zagreb							
1	Planned	18,611.71	2,104.12	199.57	19,325.55	686.81	312.55
	Actual	20,994.28	2,019.63	2,116.41	20,012.87	561.92	95.45
2	Planned	20,944.69	1,197.41	83.50	17,610.43	993.92	127.66
	Actual	21,449.74	1,278.75	313.41	17,850.29	1,306.95	1,018.91
Rijeka							
1	Planned	13,327.95	413.75	80.10	12,945.77	312.61	116.72
	Actual	14,074.82	429.43	279.40	15,456.72	326.69	103.68
2	Planned	20,260.34	463.92	150.75	18,609.42	510.93	220.77
	Actual	21,281.94	467.85	285.33	17,540.24	507.00	141.57
Split							
1	Planned	13,715.02	418.68	157.81	15,611.55	531.19	210.88
	Actual	19,148.59	465.19	181.11	17,190.96	636.59	219.38
2	Planned	20,909.87	370.47	263.39	11,451.20	249.01	67.77
	Actual	21,251.20	373.66	508.41	13,196.55	250.63	191.00
Osijek							
1	Planned	15,861.83	0.82	115.99	18,703.09	1,032.17	85.60
	Actual	16,098.09	0.96	195.46	19,065.14	946.01	217.97
2	Planned	18,872.13	1,255.17	140.52	15,906.71	667.76	79.69
	Actual	22,440.82	1,133.61	271.57	20,638.25	737.20	222.35

Table 3 shows the average number of students in 2018 of each school individually.

**Table 3. Number of students per school**

City	Zagreb		Rijeka		Split		Osijek		Total
	1	2	1	2	1	2	1	2	
Type of school									
High schools	461	618	618	291	621	570	613	580	4372
Elementary schools	364	658	579	366	394	865	368	458	4052

Table 4 shows the year of construction of each school.

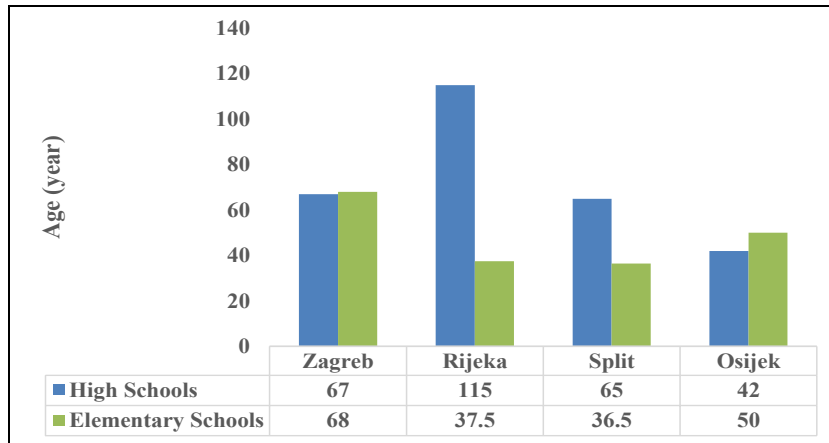
**Table 4. Year of construction of schools**

City	Zagreb		Rijeka		Split		Osijek	
	1	2	1	2	1	2	1	2
Type of school								
High schools	1956.	1948.	1896.	1912.	1983.	1982.	1978.	1960.
Elementary schools	1935.	1967.	1987.	1976.	1950.	1958.	1978.	1976.

The paper below summarizes the results of collected data for high and elementary schools in the Republic of Croatia.

#### 4.1. Results

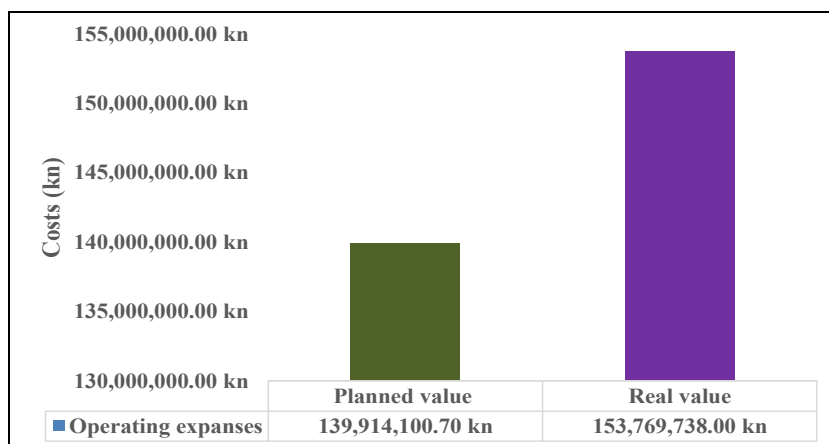
Observed schools are on average 60.1 years old. The average age of schools trough cities is shown in Figure 3.



**Figure 3. Average schools age**

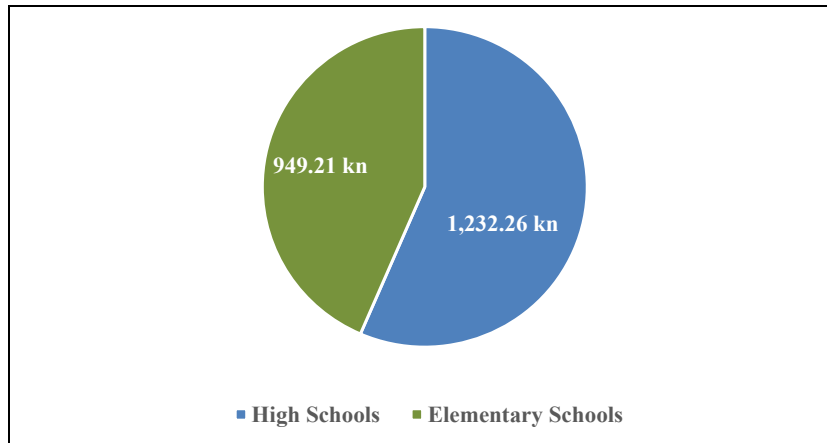
Elementary schools are the oldest in the city of Zagreb, while high schools are the oldest in Rijeka where one of the schools is protected as a cultural good.

The total operating expenses for the observed schools are shown in the graph in Figure 4. There is a visible difference between the initially planned cost values and the actual realized, and in percent, it is 10% in favor of the real values. Total operating expenses in 2018 for observed high schools are 84,713,852.00 kn (19,376.45 kn/student), while for elementary schools are 69,055,886.00 kn (17,055.05 kn/student). The observed difference can be attributed to the fact that elementary schools receive children of smaller ages who have fewer space requirements (6.5 m<sup>2</sup>, versus 8.1 m<sup>2</sup> for high school students), the number of students at the country level in elementary schools is lower than in high schools, they work more often in one shift and are less equipped in the sense of laboratories, cabinets, halls, etc. (State Audit Office, 2018).



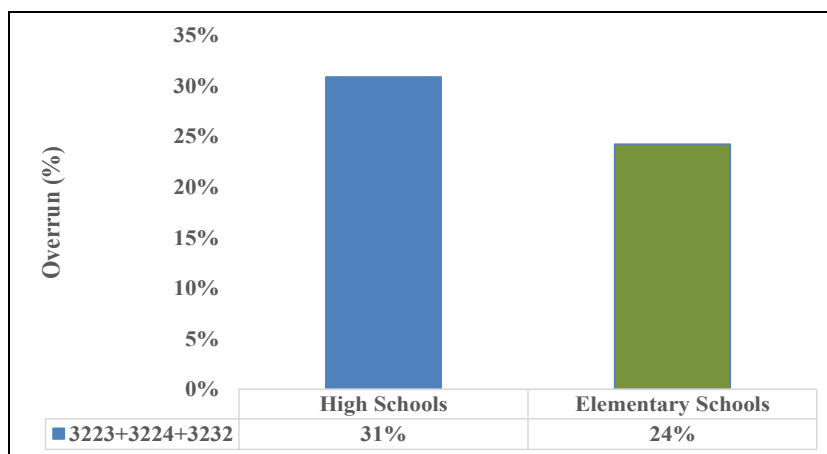
**Figure 4. Planned and actual operating expenses**

The same applies to the costs of exploitation (energy, current and investment maintenance). The costs of exploitation separately for high and elementary schools per student are shown in Figure 5. Analyzed high schools spend on average on these expenditures 1.3 times more per student than analyzed elementary schools.



**Figure 5. Energy and maintenance costs per student**

Looking at the cost overruns of energy and maintenance, planned energy costs exceeded at 11 schools, while the 5 managed to stay within the planned budget. The maximum overrun amounted to 31%. The costs of materials and services for current and investment maintenance overrun at 13 schools. These overruns are mostly fairly high, and the largest amounts are almost 1000%. The total overruns of the costs of exploitation for high and elementary schools are shown in the graph in Figure 6.



**Figure 6. Overruns of exploitation costs**

The reasons for the frequent overruns of energy and maintenance costs can be partly attributed to the factor of uncertainty in their planning. It is very difficult to foresee the energy consumption that may vary from the strength and length of winter for heating, or cooling consumption depending on the length and strength of the summer, and the like, as it is very difficult to foresee possible failures and damage that mostly affect the maintenance costs. Other reasons lie in what has been determined by reviewing the literature (State Audit Office, 2018; [1]; Alibegović and Blažević, 2010), which is that at the level of the Republic of Croatia in public facilities of social standard, among which are schools, big problems are unsatisfactory

care about maintenance and management and insufficient quality and rational management of energy consumption.

With the analysis of observed schools, it was determined that there were no signs that indicate exploitation expenses being influenced in any way and then reduced although the literature is showing great potential in that field (Danielski, 2016). It should be noted that the cost of exploitation for public schools is fully covered by the public sector (counties and cities) irrespective of their amount, which could be one of the reasons for irrational cost concerns.

What is certainly needed in the future is to influence the awareness of public bodies and schools and in particular their predecessors, take certain steps and influence spending on energy and maintenance and transfer money to other educational purposes. It is necessary to recognize the disadvantages of running educational facilities and to propose efficient measures to rationalize exploitation costs and redirect them.

The limitation of this study is that data on the physical characteristics of objects, such as surface, volume, materials, heating/cooling mode, etc, were not collected for the observed objects. Each of these features has an impact on maintenance costs and energy costs and should be taken into account in future research. It is also necessary to recognize other characteristics/factors that have an impact on energy consumption and maintenance. Authors (El-Haram and Horner, 2002; Danielski, 2016) point out that identifying such factors can help minimize and optimize exploitation costs.

## **5. Conclusion**

At the level of the Republic of Croatia, there is a decreased cost efficiency of educational facilities during the exploitation phase, primary, energy consumption and current and investment maintenance. This problem confirmed the review of the relevant literature and the analysis of the financial statements of the schools from the four Croatian cities. Although some schools in Croatia have been restored, the problems of poor maintenance and waste of energy can be repeated if they are not properly managed.

According to some authors controlling costs of exploitation can best help identify factors that affect it. According to El-Haram and Horner (2002), identification of significant factors and linkages between factors that influence maintenance costs can be used to control factors and optimize maintenance costs. Also, identifying such factors is of great help to maintenance managers in minimizing maintenance costs by gaining control of some critical factors. Factors affecting maintenance costs can be divided into four groups: building characteristics, tenant factors, maintenance factors, political factors and vandalism (El-Haram and Horner, 2002). As far as energy costs are concerned, Danielski (2016) point out that it is also very important to identify key factors that affect energy consumption in buildings to reduce total energy consumption in an efficient and effective way. These key factors would then be used to reduce energy consumption in buildings when designing new buildings and improving existing ones, and thus mitigating energy inefficiencies.

These allegations should be the cornerstone of future research where the factors affecting the cost of exploitation should be studied to control the costs of educational facilities in the



Republic of Croatia. The identification and ranking of these factors in Croatia has never been carried out, nor has their direct impact on the cost of exploitation been evaluated. The first step in the research would be to identify the most important factors that have an impact on the cost of maintaining and energy of educational facilities. On the basis of them would be through questionnaires, interviews, and direct observation on the field collected the relevant data. Processing, analysis and interpretation of results would lead to the development of the model (frame) for more efficient maintenance and use of energy in educational facilities. The model would contain concrete measures to improve the performance indicators of educational facilities, primarily in the area of energy savings and maintenance costs.

Also, as schools across the Republic of Croatia are not in equal condition, i.e. in them are not currently ruling the same level of standards and quality, the developed model should take into account that fact as well. Within the model, therefore, should develop a decision support system that would be of assistance to decision-makers in determining the importance, i.e. the priority of certain school facilities when it comes to implementing measures to improve the exploitation phase, and would be based on rating the facility state through established weight criteria. High-priority buildings would certainly be older, neglected public educational facilities, which should first be restored, and then applied to them, as well as newer facilities, standards and best management practices during the exploitation phase. Also, great attention has to be paid to the design phase of educational facilities, as previous research has shown that at this phase, it can largely affect the costs of exploitation. It is important to achieve in all project stages the affect of efficient financial resources spending so that all possible surpluses would be redirected to the primary purpose of school, which is education. The ultimate goal of the research is to achieve uniform standards and quality of school facilities and equal working conditions for all students nationwide.

This research would be important in terms of contributing to knowledge and theory, as well as good maintenance and energy consumption practices in educational facilities in the Republic of Croatia. The research would also enable the parties involved to better understand the exploitation phase before deciding to do any work on the school building.

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# Risk and Opportunities of Taking Different Procurement Routes in Construction Projects in Croatia

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## Abstract:

Project Procurement Management is a key success factor for managing complex and challenging process of delivering construction projects. One of the important areas of Project Procurement Management is determining which project delivery method is best suited for a specific project. The selection of project delivery method may affect the overall time, cost, quality and success of the project. It is influenced by the complexity, importance and size of the project, owner's management skills or contractor's management capability, financial resources, time constraint, quality, resources, project roles and responsibilities, and by the impact of risk and uncertainty. Traditional approach is today's name for Design-Bid-Build (DBB) project delivery method. The DBB method (or traditional approach) implies the sequence of separate activities (design, bid, build) and selection of the contractor only after the design phase has been completed. In Croatia, the traditional approach has been so far the most widely used project delivery method, mainly due to legal constraints. Therefore, this paper delineates project roles and responsibilities, as well as risks and opportunities, comparing the DBB method with the integrated project delivery and turnkey approaches, such as Construction Manager-At-Risk (CMR) and Design-Build (DB) methods. The aim of this paper is to highlight the potential ambiguities in Croatian legislation for the greater application of contemporary project delivery methods.

*Keywords: project delivery methods; project roles and responsibilities; Croatian legislation*

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## 1. Introduction

A key success factor for managing complex and challenging process of delivering construction projects is Project Procurement Management. Project Procurement Management presents additional considerations for planning, executing, monitoring and controlling, and closing procurement on construction projects (PMI, 2016). One of the important areas of Project Procurement Management is determining which project delivery method is best suited for a specific project. The selection of project delivery method may affect the overall time, cost, quality and success of the project. It is influenced by the complexity, importance and size of the project, owner's management skills or contractor's management capability, financial supports, time constraint, quality, resources, project roles and responsibilities, and by the impact of risk and uncertainty. Most delivery methods used today are variations of three methods: Design-Bid-Build (DBB), Construction Manager-at-Risk (CMR), and Design-Build (DB) (CMAA, 2012; CII, 1997). Traditional approach is today's name for Design-Bid-Build (DBB) project delivery method. The DBB method (or traditional approach) implies the sequence of

separate activities (design, bid, build) and selection of the contractor only after the design phase has been completed. Non-traditional forms are considered as integrated project delivery and turnkey approaches. Construction Manager-at-Risk (CMR) and Design-Build (DB) are the two most common forms of integrated project delivery and turnkey approach (Koch *et al.*, 2010). Integrated and turnkey project delivery methods combine the expert knowledge and skills of participants for all phases of design, fabrication, and construction with the intention to optimize efficiency in project cost and schedule (PMI, 2016). In both, CMR and DB project delivery methods, the owner selects the contractor at a point in time before the design is complete and seeks to involve that contractor in the design process through the use of formal design reviews that seek to enhance constructability, expedite the schedule, and maintain budget (Koch *et al.*, 2010). The DBB method involves less contractor input to the design than the CMR or DB methods (Touran *et al.*, 2009). Thus, one of the greatest advantages of CMR and DB project delivery methods is possibility to optimize construction execution through contractor's input to the design. Constructability is a concept, defined as the optimum use of construction knowledge and expertise in planning, design, procurement, and field operations to achieve overall project objectives (CII, 1986). Contractor's input to the design, by reviewing design drawings and forthcoming construction process, may detect possible risks, problems and project defects that could cause delays on site, poor performance, costs overruns and other similar failure. Consequently, the purpose of constructability review is to ensure optimum efficiency, high quality, shorter schedules and safe execution of construction, and to reduce claims and changes in orders, as well as project uncertainties and risks.

Constructability still hasn't reached significant impact in construction practice in Croatia (Galić *et al.*, 2013). Furthermore, in Croatia, the DBB method has been so far the most widely used project delivery method, mainly due to legal constraints. In the DBB method, constructability reviews are not usually welcomed by the project designers because they are perceived to be criticism rather than assistance. (Koch *et al.*, 2010). Phase separation, especially between the design phase and construction phase, often results in problems in performance, but, it can quite realistically be expected that the inclusion of the contractor during the earlier project stages, especially during the design phase, could result in better design solutions and definitely decrease the number of problems occurring during the construction (Turina, *et al.*, 2013).

Therefore, this paper delineates project roles and responsibilities, as well as risks and opportunities, comparing the DBB method with the integrated project delivery and turnkey approaches, such as Construction Manager-At-Risk (CMR) and Design-Build (DB) methods. The aim of this paper is to highlight the potential ambiguities in Croatian legislation for the greater application of contemporary project delivery methods.

## **2. Project delivery methods**

### *2.1 Design-Bid-Build, DBB*

Design-Bid-Build (DBB), or traditional approach, is considered as construction project delivery method in which the designer and contractor separately carry out project work through separate contract with the client (i.e. project owner, investor or representative of the aforesaid in this paper). The DBB method, in principle, implies, first, the design phase, and then the

selection of contractor by competitive tendering and bidding (see Figure 1). Typically used with the DBB method is lump sum contract, which is suitable if the scope and schedule of the project are sufficiently defined to allow the estimation of the project costs (Kubba, 2017). The designer is not involved in lump sum contract between the client and contractor. The client and designer form separate contract usually based on a negotiated professional fee. Since the DBB method implies a choice of contractor only after the completion of the design phase, there are great risks for the possible problem formations and needs for project modification during the construction phase. Subsequent modifications in the project documentation, i.e. modifications in design, are then complex, costly and time-consuming. The DBB method, therefore, involves the sequence of separate activities (design, bid, build) and thus, compared to other methods, like Construction Manager-at-Risk (CMR) and Design-Build (DB), results in the longest duration for project delivery.

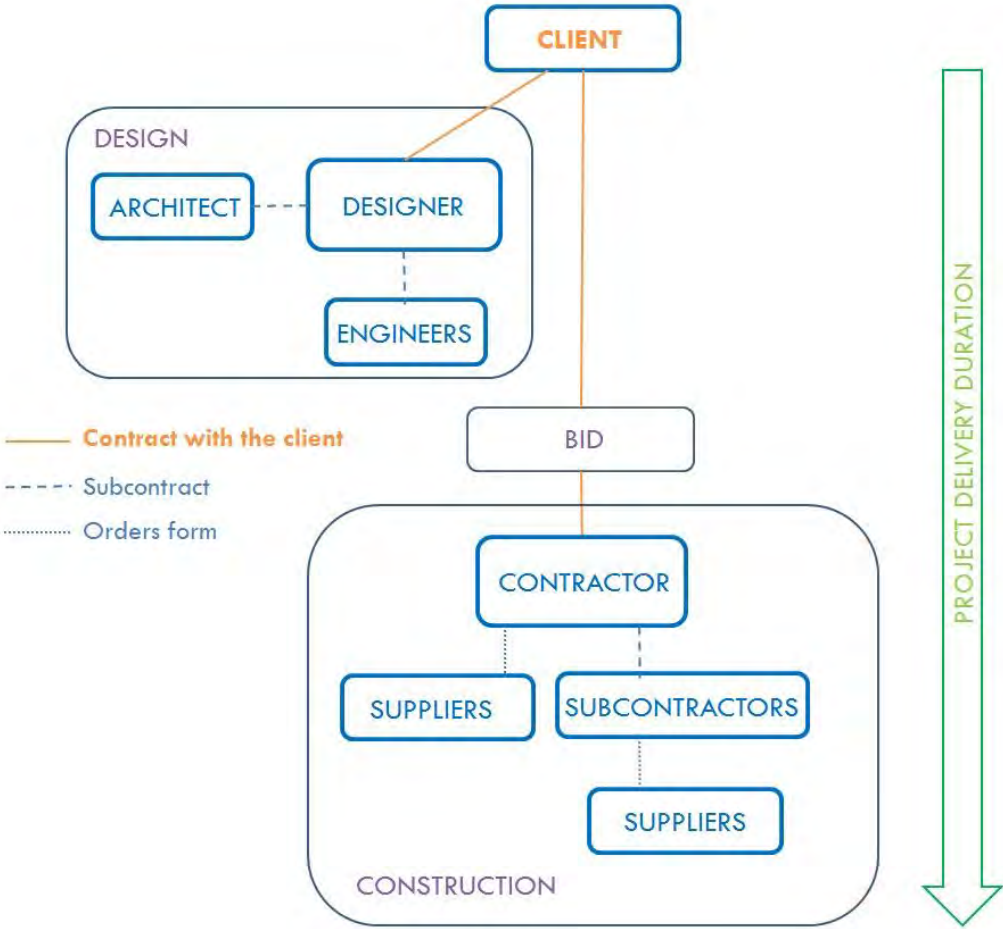


Figure 1. An example of structure of Design-Bid-Build (DBB) project delivery method with connections

In addition to the aforementioned drawbacks, other disadvantage of the DBB project delivery method is unknown cost of construction works until the bids are received, furthermore, costs of construction works may be too high and impossible to afford for the client, which (as well as defects in design detected during the construction) cause project re-designing, as well as project delays and additional costs. Disadvantages also includes designing without contractor’s feedback about it, the choice of the contractor is primarily based on price proposal,

not on qualifications and references, and also, the client should have significant expertise and involvement in project progress. In the DBB method, the client is in the inconvenient role of “the middleman” between the designer and contractor, so there are, as well, possibilities of tense relationships between the designer and contractor, and any project errors may result with “finger-pointing” and with conflicts between the designer and contractor. Some highlighted advantages of the DBB project delivery method are client controls over the design and construction phase, linear and straight-forward structure of project delivery method (i.e. easy to understand), and the existence of maximum competition among contractors during the bids.

## 2.2 Construction Manager/General Contractor (CM/GC) or Construction Manager at Risk (CMR)

Construction Manager/General Contractor (CM/GC) project delivery method is also known/termed as Construction Manager at Risk (CMR) (Borowiec *et al.*, 2016). The CMR method implies separate contracts between the designer and contractor with the client. Like in the DBB method, the client and designer form separate contract, usually based on a negotiated professional fee. But, unlike in the DBB method, the client searches for the contractor at the early stage of design (in about 30 % progress of the design phase) (see Figure 2). Selection of the contractor is based on contractor’s professional qualifications, experience and competence. A contract with the contractor has two parts: pre-construction services and construction (Gransberg *et al.*, 2013). Therefore, contractor’s work scope, apart from construction performance, also include performing activities and obligations during the design phase (i.e. pre-construction services) like feasibility study, constructability reviews, cost and time estimations for construction, etc. In order to meet the contractual requirements, the contractor must communicate with the designer. The stated responsibilities and activities of the contractor are aimed at managing constructability and reducing risks, uncertainties and failures during the construction phase of a project. Once the design reaches about 60 % (or more) progress of the design phase, negotiations, between the client and contractor, on construction part of contract are initiated. Up to (maximum) 90 % progress of the design phase and on the basis of defined scope, time of completion, and total construction cost, a construction part of contract is negotiated, most often in the form of Guaranteed Maximum Price type of contract, (GMP). A guaranteed maximum price (GMP) should be established at a point where the design is sufficient advanced and the contractor can furnish a price with a minimal contingency for possible increases in scope (Gransberg *et al.*, 2013).

Some highlighted advantages of CMR project delivery method are selection of the contractor primarily based on contractor’s professional qualifications and references (not on lowest construction bid price), and the contractor’s obligations to provide preconstruction services (through contractor’s input to design) for the purpose of managing constructability and reducing project uncertainties and risks. Some highlighted disadvantages of CMR method are non-competitive price offer for construction, potential risks if the guaranteed maximum price (GMP) is established in the stage of insufficient progress of the design, and also, potential risks of contractual “expectation” (with possibility of ineffectiveness or slow progressions) for communication and coordination between the designer and contractor.

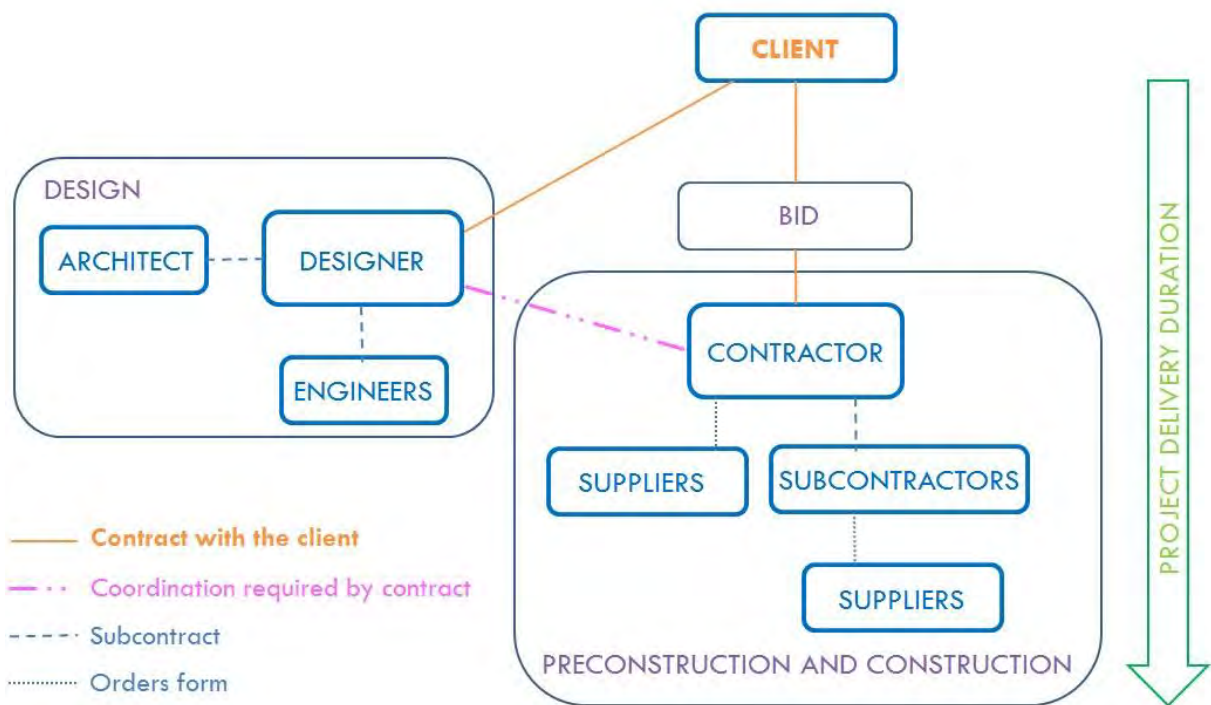


Figure 2. An example of structure of Construction Manager-at-Risk (CMR) project delivery method with connections

### 2.3. Design-Build, DB

In Design-Build (DB) project delivery method, the responsibility for designing and constructing is taken over by a separate design-build organization (or business entity). This organization may refer to a specially formed association and co-operation between the designer and contractor involved in the project. Both, design and construction are covered by a single contract with the client (see Figure 3). The design-build organization represents a single point of contact with the client so the client does not have to be a link, or the “middleman”, between the designer and contractor. A single point of contact has been proven to foster better communication, lessen confrontation roles between design and construction, and accelerate project delivery which is perhaps its biggest advantage (Kubba, 2017). Lump Sum contract is the most common contract type between the client and the design-build organization (Bogus *et al.*, 2010). Second one is Guaranteed Maximum Price (GMP) type of contract (Chen *et al.*, 2016). All the subcontractors and suppliers are subsequently solicited and retained by the design-build organization. The formed design-build organization manages all the subcontracts and orders forms with the subcontractors, suppliers and resources providers.

In design-build organization, clear communication and effective collaboration play an important role in managing project progress and success. Co-operation between the designer and contractor enables optimization and coordination of design and construction phases. The role of the client is to provide a feedback to the design-build organization for project development proposals. Some highlighted advantages of the DB method are high potentials for rapid project delivery and costs savings because of possibility to overlap the design and construction phases of a project, efficient form of synthesis between the designer and



contractor, team-oriented project delivery approach, team members working under the same contract, solutions based on common collaboration and efforts, risk reduction of construction delays because of the less possibility of mismatches between the design and construction and, consequently, necessary corrections. For the client, the primary benefit includes the simplicity of having one party responsible for the development of the project and the time saving as a result of overlapping design and construction phases (Al-Reshaid and Kartam, 2005). Some highlighted disadvantages of the DB project delivery method are the risks of higher final costs than initial assessment, possible problems if the design-build organization is inexperienced with DB project delivery method and potential risks due to self-willed engagement of the client.

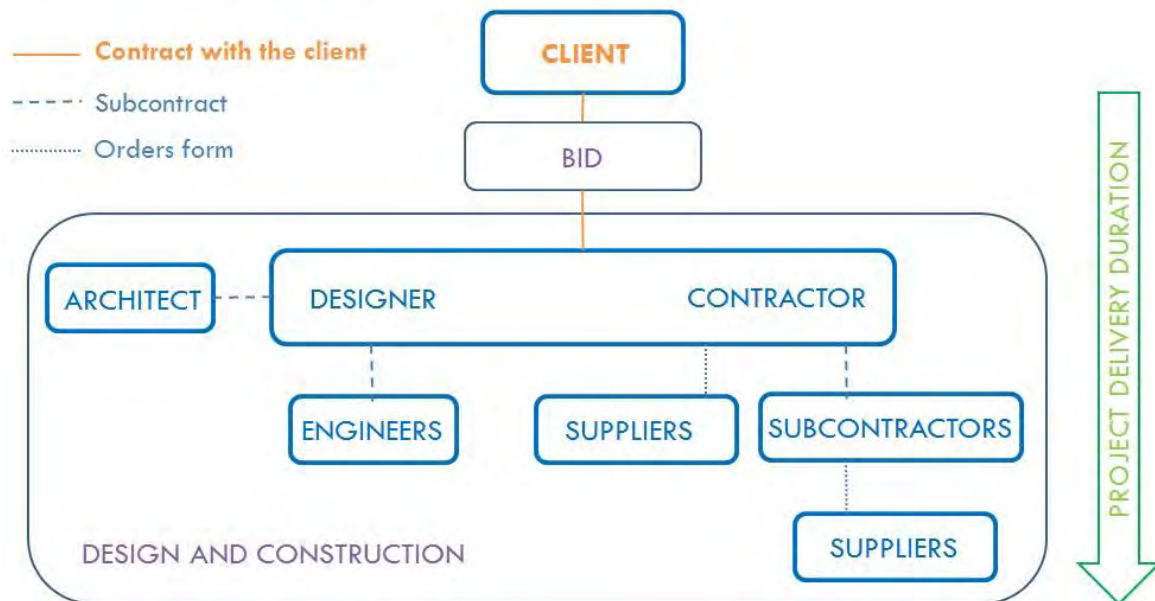


Figure 3. An example of structure of Design-Build (DB) project delivery method with connections

### 3. DBB, DB and CMR comparison regarding literature review

Design-Bid-Build (DBB) project delivery method implies obtaining permits and selection of the contractor only after the design phase has completed. Commonly in the DBB method, the selection of the contractor is happening after obtaining permits. The Construction Manager-at-Risk (CMR) method implies obtaining permits, approximately, between 90 to 100 % progress of the design phase. In the CMR method, the contractor is selected at the early progress of the design phase (in about 30 % progress of the design phase). Because of the selection of the contractor at the early progress of the design phase, and obtaining permits before the end of the design phase, CMR method, compared to DBB method, results with faster project delivery method.

In the CMR method, once the design reaches about 60 % (or more) progress of the design phase, negotiations, between the client and the contractor, on construction part of contract are initiated. If than happens that the offer (GMP), provided by the contractor, is too high (to the client), the client may decide to reject the given offer and continue with the DBB project delivery method.

Design-Build method provides opportunities for speed and innovation because design and construction activities are overlapped (Tran *et al.*, 2013). In the DB method, permits are obtained within the Final Design process. Preliminary Design (Preliminary Design, according to Croatian laws translated into English, is considered as conceptual design) involves site investigations, making of architectural, civil, mechanical and technical engineering design concepts, producing sufficient number of drawings with necessary structural and installation components, initial estimations of construction operating cost and schedule, project revisions, and other preliminary design needs depending on the project size and complexity. Final Design (Final Design, according to Croatian laws translated into English, is considered as main design) involves final decisions and solutions of design problems, making of architectural, civil, mechanical and technical engineering detailed drawings, accurate estimations of construction operating cost and schedule, final selection of the construction materials, equipment and machinery, verification of the economically viable of the project, and other necessary final design decisions. After obtaining permits, construction may start. In the DB method, construction may start within the duration of the Final Design phase of the project. Due to the selection of design-build organization at the very beginning of the project and possibility to obtain permits within the Final Design phase, the DB method, compared to DBB and CMR methods, can result with fastest project delivery method (see Figure 4).

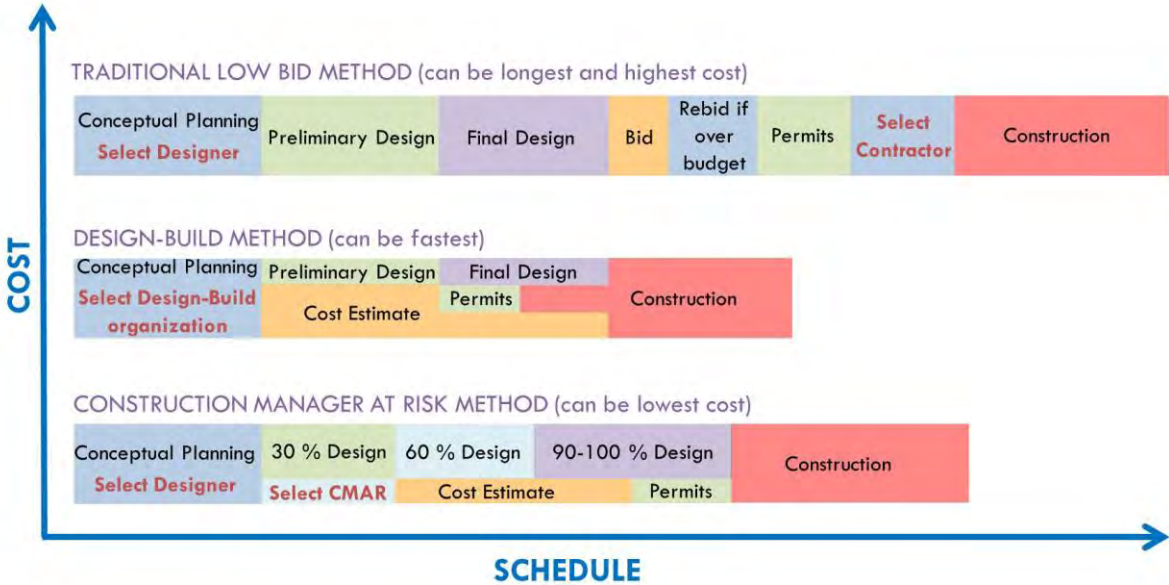


Figure 4. DBB, DB and CMAR comparison (adapted from Robertson *et al.*, 2017)

Although in the DBB method the client may select the contractor with the lowest cost offer for construction, it should be noted that the lowest construction cost doesn't have to meet the requirements for the highest or required construction quality. In the DBB method, until the bids are received, the construction cost is unknown, which can result in favorable or in excessive and unaffordable construction costs. Therefore, during the design phase of the DBB method, there is great uncertainty for construction cost and, as well, poor cost control. Also, in the DBB method, during the construction phase, there are great risks for project re-designing need,

especially for large and complex projects, causing delays and additionally increasing project delivery cost. Due to all above-mentioned limitations and risks, the DBB method, compared to the CMR and DB method, can result with the highest project delivery cost, especially for large and complex projects (see Figure 4).

The DB method implies the start of project cost estimations at Preliminary Design of the project design phase. Cost estimating for a DB project delivery method can be difficult say when design documents are preliminary and liable to change over the course of the project. (Kubba, 2017). Because of the possibility of (too) early project delivery cost establishment, there are risks of higher final project cost than initial estimation. To address this situation, contracts are often written to allow for unexpected situations without penalizing either the design-build organization or the client (Kubba, 2017).

In the CMR method, construction cost is established in about 60 % to 90 % progress of the design phase. Due to possibility and recommendation for establishing the construction price (GMP) at a point where the project design is sufficient advanced, the CMR method from the aspect of construction cost control, and compared to the DBB and DB method, can result with the lowest project delivery cost and highest cost control (see Figure 4).

By following the aforementioned characteristics of project delivery methods from the aspects of project schedule and cost, Schedule-Cost diagram (see Figure 4) shows that the DBB method can be project delivery method with the longest schedule and highest cost. Furthermore, the DB method can be the fastest project delivery method, and finally, the CMR method can be project delivery method with the lowest cost and highest cost control.

Risk allocation for project control and schedule, between the client and contractor, is different in the DBB, CMR and DB methods. In considering risk allocation, the client should strive to assign risks to those parties that can best exercise control over those aspects (CMAA, 2012). In the DBB method, client has the main responsibility for project control and schedule. Contractors bid the project exactly as it designed with the lowest responsible, responsive bidder awarded the work (Kubba, 2017). Unlike the DBB method, in the DB method, client can allocate risk for project control and schedule to the design-build organization. This type of risk allocation minimizes the project risk for the client. In the CMR method, contractor collaborates together with the client and designer. Hiring a contractor during the design phase, allows the contractor to work directly with the designer and circumvent any potential design issues (Kubba, 2017). Figure 5 shows the approximate risk allocation for project control and schedule, between the client and contractor. The DBB method implies allocation of the highest risk for project control and schedule to the client, but the DB method implies highest risk to the design-build organization. The CMR method implies approximately equal risk allocation for project control and schedule, between the client and contractor.

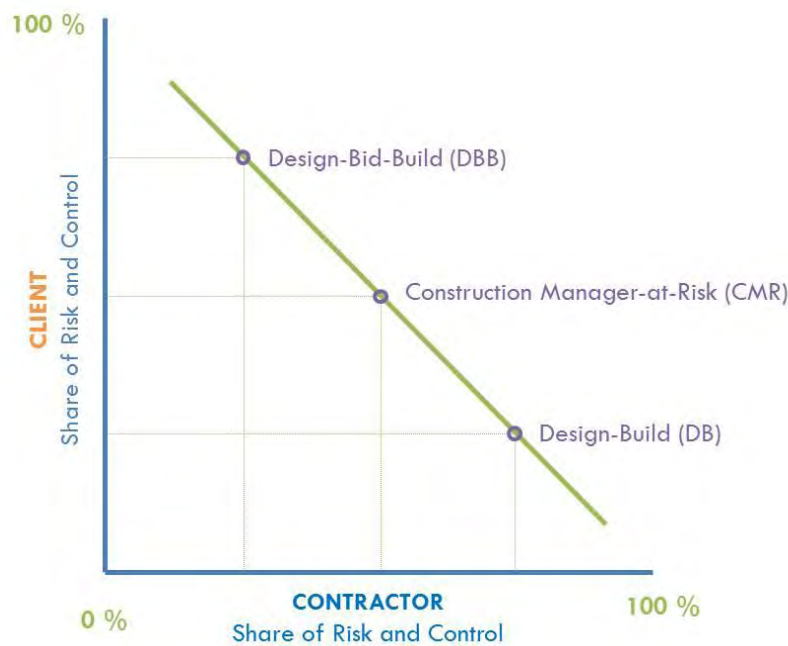


Figure 5. The approximate risk allocation for project control and schedule (adapted and modified from: Gransberg and Shane, 2010)

The client is person responsible for determining the type of contract to be used on a particular project (Kubba, 2017). Contracting and compensation methods for professional services and construction services will generally fall into one of three categories: Fixed Price or Lump Sum (LS), Guaranteed Maximum Price (GMP) and Reimbursable type of contracts (CMAA, 2012). These contract types are not exclusively defined only for one project delivery method and can be used vary.

Fixed Price or Lump Sum types of contracts are suitable for projects that are sufficiently defined, which allows for an estimate of the total project cost (PMI, 2016). This Contract type places the maximum risk and full responsibility for all cost and resulting profit or loss upon the contractor (Kubba, 2017).

GMP type of contract will typically include a base cost along with several allowances and contingencies that, depending on their ultimate use, may result in a final cost below the stated guaranteed maximum price (GMP). With this type of contract, the contractor is reimbursed for actual costs incurred for labor, materials, equipment, subcontractors, overhead, and profit up (Kubba, 2017). Any “savings” may fall to the client or may be shared with the entity providing the GMP (CMAA, 2012). The GMP format allows owners to minimize risk when proceeding with work ahead of final drawings e.g. when a design is less than 100 % complete (Kubba, 2017).

Reimbursable contracts come in a variety of forms, and sometimes coupled with a not-to-exceed maximum price (CMAA, 2012). In Reimbursable type of contract payment can be based on a fixed amount for each unit of work (Unit Price), on actual cost plus fixed/percentage/incentive/award fee (Cost Plus) or on actual hours spent and resources expended on the work performed. According to Kubba (2017):

- In Unit Price form of reimbursable contract, the contractor is paid as the contract proceeds by requiring that the actual quantities of work completed is measured, and these quantities multiplied by the pre-agreed per-unit price. For the contractor, this removes some of the risk in the bidding process because payment is based on actual quantities and not lump sum. The contractor's unit price must cover both direct and indirect costs, overheads, contingencies, and profit. For this reason, the owner usually provides fixed quantities for contractors to use as the basis of their unit price costing.
- In the Cost Plus form of reimbursable contract, the client reimburses the contractor for all costs associated with the contract in addition to a fee covering the contractor's profit and non-reimbursable overhead costs. This is the most beneficial contract for the contractor, since any additional costs will be covered, thus guaranteeing them a profit regardless of project cost. The various types of additional costs should be discussed with the contractor at the time the bid is being reviewed. This type of contract is usually used for projects where the scope of the work is indeterminate or very uncertain and the kinds of labor, material, and equipment needed are also very difficult to ascertain.

Figure 6 shows risk scale relative to the client and contractor associated with the contract type. Fixed Price or Lump Sum type of contract takes the maximum risk and full responsibility for all cost and resulting profit or loss upon the contractor. Unlike the Fixed Price or Lump Sum, Cost Plus is the most beneficial contract for the contractor, because the client reimburses all costs associated with the contract in addition to a fee covering the contractor's profit and non-reimbursable overhead costs.

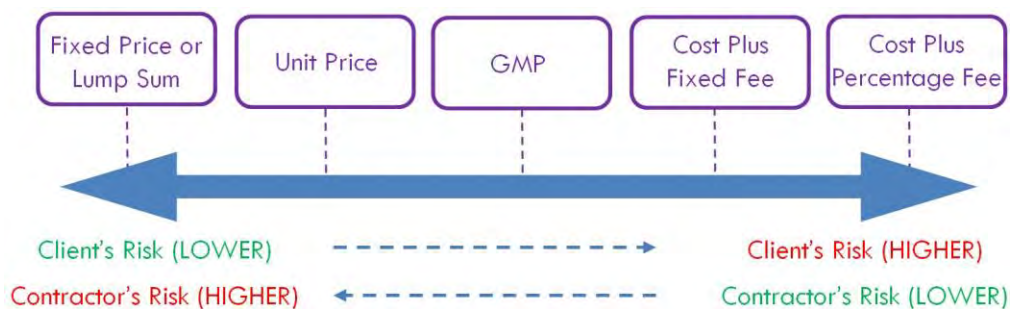


Figure 6. Risk scale by the client or contractor depending on the selection of contract type (adapted from CII: <https://www.construction-institute.org/topic-summaries/rt-201-300/reimbursable-contracts>)

Selection an appropriate method for project delivery can be also considered from the aspects of project type and complexity. DBB method is most suited for less complicated projects that are budget sensitive but not necessarily schedule sensitive and not subject to change (Kubba, 2017). CMR greatly facilitates phased construction when that is a requirement for a given project (Touran *et al.*, 2009). DB is best suited to conventional projects for which project requirements can be clearly defined and for which expertise is widely available (CMAA, 2012). According to Molenaar *et al.*, (2014):

- DBB is useful for projects that can be designed to or near 100 % complete. Typical and common projects will benefit the most from the use of DBB as the delivery

method. Projects that involve high risk and many unknowns as well as projects that have a limited amount of time to complete the project will not achieve the benefits of DBB and another delivery method might be a better choice.

- The CMR delivery method is most advantageous on project where the design is complex, difficult to define, subject to change and there are several design options, and when the project is sequence or schedule sensitive. The CMR method is less suitable for straight-forward projects, projects with easily defined scope and low risk, and projects that lack schedule sensitivity.
- The DB method is not suited for every project. This method works best for project that require acceleration, projects that have unique opportunities to appropriately transfer risk to the design-build organization, and on projects with opportunities for innovation. This method has been used successfully on projects for which (California DOT, 2008): a compressed schedule was needed, schedule certainty was needed, early costs certainty was required, project scope could be adequately defined without 100 % complete plans and/or specifications and/or estimates, project quality could be defined through minimum design, and where minimal third party risks existed or could be mitigated.

Tables 1-3 provide an overview of the highlighted disadvantages and advantages for each project delivery method with the best suited project type regarding literature review. Because each of the three main delivery methods (DBB, CMR and DB) can be applied to project of all size, it seems clear that project size needs to be considered in combination with other issues, such as schedule, risk management, and staffing in order to determinate an appropriate project delivery method (Touran *et al.*, 2009).

Table 1. Highlighted disadvantages and advantages with the best suited project type for the DBB method

	Design-Bid-Build (DBB)
Highlighted disadvantages:	<p>Designing without contractor's feedback about it, and selecting a contractor only after the completion of the design, which may cause possible problem formations and needs for project modification during the construction phase,</p> <p>Unknown cost of construction works until the bids are received,</p> <p>The choice of contractor is primarily based on price proposals, not on qualifications and references,</p> <p>The client/owner/investor should have significant expertise and involvement in project progress and can be in the inconvenient role of "the middleman" between the designer and contractor,</p> <p>Project errors may results with conflicts and tense relationships between the designer and contractor.</p>
Highlighted advantages:	<p>Client/owner/investors control over the design and construction phase,</p> <p>Structure of the DBB method is linear and straight-forward (i.e. easy to understand),</p> <p>The existence of maximum competition among contractors during the bids.</p>
DBB project delivery method works best for:	<p>Less complicated projects,</p> <p>Typical and common projects,</p> <p>Budget sensitive projects,</p> <p>Projects that are not subject to change in design.</p>

Table 2. Highlighted disadvantages and advantages with the best suited project type for the CMR method

	Construction Manager-at-Risk (CMR)
Highlighted disadvantages:	The client/owner/investor searches for the contractor (based on contractor's professional qualifications, experience and competence) at the early stage of design, which (later) cause non-competitive price offer for construction. Potential risk if the establishment of a price offer for construction is in the stage of insufficient progress of design.
Highlighted advantages:	Selection of the contractor is primarily based on contractor's professional qualifications and references (not on lowest construction bid price), The contractor's obligations to provide preconstruction services (through contractor's input to design) for the purpose of managing constructability and reducing project uncertainties and risks.
CMR project delivery method works best for:	Projects with complex design, Projects with several design options, Projects with difficult to define design, Schedule sensitive projects, Projects that are subject to change in design, Phased construction.

Table 3. Highlighted disadvantages and advantages with the best suited project type for the DB method

	Design-Build (DB)
Highlighted disadvantages:	Risks of higher final costs than initial assessment, Possible problems if the design-build organization/business entity is inexperienced with the DB project delivery method, Potential risks due to self-willed engagement of the client/owner/investor.
Highlighted advantages:	High potentials for rapid project delivery and costs savings because of possibility to overlap the design and construction phases of a project, Efficient form of synthesis between the designer and contractor, Team-oriented project delivery approach, Team members working under the same contract, Solutions based on common collaboration and efforts, Risk reduction of construction delays because of the less possibility of mismatches between the design and construction and, consequently, necessary corrections.
DB project delivery method works best for:	Conventional project, Projects where project requirements can be clearly defined without 100 % complete of the design, Projects that require acceleration or where compressed schedule is needed, Projects with early costs certainty, Expertise of design-build organization/business entity is widely available.

#### 4. Analysis of Croatian legislation in relation to the project delivery methods

##### 4.1. Characteristics of Croatian legislation in relation to the project delivery methods

Design-Bid-Build has been the most widely used construction delivery method and also the one with which most clients are familiar (Kubba, 2017). In Croatia, the DBB method has been also so far the most widely used project delivery method, because of, as previously stated, it is the most familiar and common method, but the other reasons were legal constraints in Croatia. For example, in the initial form of Statute of Croatian Chamber of Architects (*article*

72., paragraph 13., *Official Gazette, No. 131/2010*) (in Croatian: članak 72., stavka 13., *Statut Hrvatske komore arhitekata, Narodne novine, broj 131/2010*) it was stated that the lighter violation of architect's duty is performing offer to the client for, both, designing and construction works. Another example of imposed conditions for applying the DBB method was the restriction in the Physical Planning and Building Act (*article 179., paragraph 3., Official Gazette, No. 76/2007*) (in Croatian: članak 179., stavka 3., *Zakon o prostornom uređenju i gradnji, NN 76/2007*) by which a designer cannot be an employee of a contractor on the same building. Today's current Building Act (*Official Gazette, No. 153/13, 20/17 and 39/19*) (in Croatian: *Zakon o gradnji, NN 153/13, 20/17, 39/19*) and Statute of Croatian Chamber of Architects (*Official Gazette, No. 140/2015, 43/2017*) doesn't have those legal restrictions.

Legislation relating to construction projects in Croatia is mainly written in the shape that follows structure of the DBB project delivery method, separating the designer and design process from the contractor and construction process. For example, a building permit, that legally allows the start of construction works, can be obtained only after the main design has completed. Conceptual design (Preliminary Design) together with the main design (Final Design) and detailed design (Working Design) can form the design phase of the project. Previously stated does not apply in the case of simple and other construction works and related works, where, in certain cases, construction is allowed without main design and building permit. Conditions for simple and other construction works and related works are prescribed in Rulebook of simple and other construction works and related works (*Official Gazette, No. 112/17*) (in Croatian: *Pravilnik o jednostavnim i drugim građevinama i radovima, NN 112/17*). This kind of simple construction works is not covered by this paper.

In Croatia, for most private projects, the main design is the end result of the design phase. The main design is a set of aligned designs, which provides the technical solution of a construction work and attests the compliance with the essential requirements for the construction work (*articles 68.- 73., Building Act, Official Gazette, No. 153/13, 20/17 and 39/19*). Also, as previously stated, the main design is an inevitable condition for obtaining building permit. There is only one case in which the main design, is not completely finished, but meets the conditions for issuing a building permit, and that is in case when the main design is not providing the technical solution of the finishing of floors, walls and ceilings, partition non-bearing walls and the installation distribution within the construction work (for "Rohbau" construction work). Beside the main design, more developed main design is the detailed design. The detailed design develops the technical solution laid down by main design (*article 74., Building Act, Official Gazette, No. 153/13, 20/17 and 39/19*). Detailed design has to be developed for the construction works planned by the State plan of Croatia for spatial development or in the cases where the client and contractor have agreed so in a building contract. Unlike the main design, the detailed design may be adapted to the dynamics of construction works (*article 34., Rulebook on compulsory content of documentation of construction projects, Official Gazette, No. 64/14, 41/15, 105/15, 61/16 and 20/17*) (in Croatian: članak 34., *Pravilnik o obveznom sadržaju i opremanju projekata građevina, NN 64/14, 41/15, 105/15, 61/16, 20/17*).



According to the Building Act (*article 53, Official Gazette, No. 153/13, 20/17 and 39/19*) the contractor is a person who constructs or carries out certain works on the construction work. In this case, the law (obviously) mostly limits the scope of the contractor's work only to the works on the construction site. Pre-construction services of the contractor during the design phase (like constructability review), does not appear in any law, related rulebook or other regulations, relating to construction projects in Croatia. In the Civil Obligations Act (*article 630, paragraph 1, Official Gazette, No. 35/05, 41/08, 125/11, 78/15, 29/18*) (*in Croatian: članak 630, stavka 1, Zakon o obveznim odnosima, Narodne novine, broj 35/05, 41/08, 125/11, 78/15, 29/18*) it is stated that, where the construction contract contains a "turn-the-key" provision or some other similar provision, the contractor undertakes to carry out independently all the work needed for construction and use of the construction. Construction contract with a "turn-the-key" provision, or some other similar provision, may also include designing (*article 630, paragraph 1, Civil Obligations Act, Official Gazette, No. 35/05, 41/08, 125/11, 78/15, 29/18*). The aforementioned legal regulations may be used to deliver a single contract for designing and construction works with the client. However, it is still necessary to respect the sequence of separate activities, for example first making the main design, afterward, obtain permits and finally, performing construction works, i.e. following the provisions of the Building Act (*Official Gazette, No. 153/13, 20/17 and 39/19*). With the existing legislation relating to construction projects in Croatia, overlapping of the design and construction phases of a project, which is characteristic for the Design-Build method, is questionable to achieve.

In cases of project delivery with an costs estimate for procurement of goods and services higher than 200 000 HRK (Croatian Kuna) and/or an costs estimate for works higher than 500 000 HRK it is compulsory to apply the Law on Public Procurement (*article 12, paragraph 1, Official Gazette, No. 120/16*) (*in Croatian: Zakon o javnoj nabavi, NN 120/16*) and to fulfill the conditions of a public or sectoral (or other entity) contracting authority. According to the Law on Public Procurement (*article 3, paragraph 32, Official Gazette, No. 120/16*) the public procurement contract is a contract between one or more business entities and one or more contracting authority for the purpose of performing works, delivery of goods or providing a service. Furthermore, the public procurement contract of works in construction presents a contract whose object can be construction works or design and construction works (*article 3, paragraph 33, Law on Public Procurement, Official Gazette, No. 120/16*). The public or sectoral contracting authority determines the procurement object in a way that represents a technical, technological, design, functional or other objectively determinable whole. The description of the procurement object contains the technical specification, which, if necessary, is completed with drafts, project documentation, drawings, models and samples, and similar. In cases of mixed contracts, whose procurement objects are: partially services and partially goods, or, partially services and partially social and other special services, the main object is the one, which has higher estimated value. If the various parts of mixed contracts are objectively detachable, the contracting authority may decide to award separate contracts for separate parts or to award a single contract. Experience of investing public funds for meeting public needs, so far, has at times, shown inadequate knowledge and even insufficient effort to rationally and conscientiously manage public funds (Car-Pušić, 2014). The public procurement of works in

construction is a complex procedure and requires high level of knowledge of legal laws, regulations and obligations of involved parties in construction activities.

The DBB method generally and commonly doesn't require a contract-regulated cooperation and coordination of works between the designer and contractor. Therefore in conditions that require mutual collaboration, for example making the detailed design (which may be adapted to the dynamics of construction works), there is a high level of risk of ineffective and conflict collaboration due to (adverse) considerations it's a part of the job, from the aspect of the designer, within contractor's obligations, i.e., from the aspect of the contractor, within designer area of work. According to the Turina (2008) research, related problem to the previous mentioned limitation is that the main design is usually not developed sufficiently well because of the short time in which permits wants to be obtain. Shortcomings of the main project are later attempted to be corrected in detailed design causing project delays and tense relationships between the contractor and designer. Furthermore, if design problems occur during the construction works, the client has no coercion instrument towards the designer, therefore the client force the contractor to solve the problem (Turina, 2008). The above-mentioned possible scenarios of the DBB method are particularly difficult to solve for a complex type of project.

For the purpose of overcoming of some disadvantages of the DBB method and fulfilling the constructability goals, the contractors can be non-formal involved in the design phase. In Turina (2008) research, this aforementioned method has got the following name: *traditional model with elements of a novated design&build model*. In the novated DB, the client novates its design team to the successful bidder to carry out the detailed design as the contractor's consultant (Xia *et al.*, 2012). As a consequence of novation, the design team's obligation to the client gets transferred to the contractor who becomes responsible for carrying out the detailed design work at a later stage of project life cycle (Doloi, 2008). However, in Turina (2008) research it is stated that the constructability goals in a *traditional model with the elements of a novated design&build model* are still minimally achieved.

## 5. Discussion

In Croatia, the DBB method has been so far the most widely used project delivery method. Also, constructability still hasn't reached significant impact in construction practice in Croatia. Constructability is defined as the optimum use of construction knowledge and expertise in planning, design, procurement, and field operations to achieve overall project objectives (CII, 1986). In comparison with the Construction Manager-at-Risk (CMR) and Design-Build (DB) methods, the contractor in the DBB method has less input to the design. The CMR and DB methods imply inclusion of the contractor in the design process, exactly because of the intention to manage constructability and reduce project uncertainties and risks. Building Act (*Official Gazette, No. 153/13, 20/17 and 39/19*) limits the scope of the contractor's work only to the performing works on the construction site. Pre-construction services of the contractor during the design phase (like constructability review), does not appear in any law, related rulebook or other regulations, relating to construction projects in Croatia. To overcome this limitation, it seems that the contractor should be forced to perform any other activities that are beyond constructing or carrying out certain works on site. But, is the contractor willing to accept this,

because it is not within contractor obligation (and knowledge) under the Building Act (*Official Gazette, No. 153/13, 20/17 and 39/19*)? Problem of lack of constructability in construction practice in Croatia, should be first appropriately resolved by legislation that more clearly permits the application of integrated project delivery and turnkey approaches (such as CMR and DB), and then should be working to raise the awareness of it.

One of the DB method characteristics is overlapping of the design and construction phases of a project. The DB method is best suited for conventional project with clearly defined requirements and for which design-build organization has widely experience. In Croatia, overlapping of the design and construction phases, in order to accelerate project delivery, is questionable to achieve. Generally, the DB method implies obtaining permits within the duration of the Final Design (i.e. main design). But in Croatia, according to the Building Act (*Official Gazette, No. 153/13, 20/17 and 39/19*), it is necessary to respect the sequence of separate activities, for example, first making the main design, afterward, obtain permits and finally, performing construction works. There is only one case in which the main design, is not completely finished, but meets the conditions for issuing a building permit, and that is in case when the main design is not providing the technical solution of the finishing of floors, walls and ceilings, partition non-bearing walls and the installation distribution within the construction work (for “Rohbau” construction work). But this exception in scope of the main design just represents one legal aspect of fulfilling the conditions for issuing a building permit, not the overlapping of the Final Design phase (i.e. making the main design) and construction works. Therefore, with this kind of regulation in Croatia, it is questionable to meet the appropriate conditions for compressed schedule, i.e. overlapping of the design and construction phase of a project.

## **6. Conclusion**

The Design-Bid-Build (DBB) project delivery method (or traditional approach) is most suited for less complicated, typical and common projects that are budget sensitive and not subject to change in design. For complex design projects, or projects that involves high risks and many uncertainties, or projects that are schedule sensitive and require acceleration, achieving overall project objectives and project success may not be possible to realize with the application of the DBB method. Non-traditional forms are considered as integrated project delivery and turnkey approaches, where the two most common forms are Construction Manager-at-Risk (CMR) and Design-Build (DB) project delivery methods.

This paper gives models of structure of project delivery methods in relation to the activities of design and construction phases, with contractual relationship between participants (Figures 1-3). Tables 1-3 provide an overview of the highlighted disadvantages and advantages for each project delivery method with the best suited project type. But, selection of the appropriate project delivery method should be also considered in combination with other issues such as client’s management skills or contractor’s management capability, financial resources, time constraint, quality, resources, project roles and responsibilities, and by the impact of risk and uncertainty. For the DBB method, one of the highlighted disadvantages is designing without contractor’s feedback about it, while one of the highlighted advantages is the existence of maximum competitions among contractors during the bids. Furthermore, for the CMR method

one of the highlighted disadvantages is non-competitive price offer for construction, while one of the highlighted advantages is the contractor's obligations to provide preconstruction services (through contractor's input to design) for the purpose of managing constructability and reducing project uncertainties and risks. Finally, for the DB method, one of the highlighted disadvantages are possible problems if the design-build organization/business entity is inexperienced with the DB project delivery method, while some of the highlighted advantages are single point of contact (i.e. single contract) with the client, and high potentials for rapid project delivery and costs because of possibility to overlap the design and construction phases of a project. In both CMR and DB project delivery methods, the contractor is involved in the design process through constructability reviews to ensure optimum efficiency, high quality, shorter schedules, safe execution of construction, and to reduce claims and changes in orders, as well as project uncertainties and risks. Comparison of project delivery methods served as a platform for the analysis of the application of considered models in the context of Croatian legislation.

Legislation relating to construction projects in Croatia is mainly written in the shape that follows structure of the DBB project delivery method, separating the designer and design process from the contractor and construction process. In Croatia, the DBB method has been so far the most widely used project delivery method because, it is the most familiar and common method, but the other reasons were legal constraints in Croatia. In today's Croatian legislation those legal constraints were removed. Croatian legislation no longer expressly forbids the applications of integrated project delivery and turnkey approach. However, there are some potential ambiguities for managing those project delivery methods, such as managing the CMR and DB methods. One of the potential ambiguities in Croatian laws, regulations and obligations, relating to construction projects, arises in the areas for pre-construction services (like constructability review) and overlapping of the design and construction phases (for example, making the main design and start of construction works) of a project. Respectively, Croatian legislation does not specify any contractor's obligation for contractor's input to the design, by reviewing the design drawings and forthcoming construction process, in order to manage constructability. Also, Croatian legislation does not specify how to meet the appropriate conditions for compressed schedule (i.e. overlapping of the design and construction phase of a project), specific characteristic of the DB method. It is of great importance to more clearly resolve these issues. Legislation should not have any ambiguities or obstacles that prevent any kind of development and prosperity. Future research (after a clearer resolution of mentioned issues in Croatian legislation) can be based on the realization of the CMR and DB methods in Croatia, in the context of Croatian legislation, project type and complexity, client's management skills or contractor's management capability, financial resources, time constraint, quality, resources, project roles and responsibilities, and by the identified limitations in implementation.

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# Efficiency of Insurance as a Risk Management Tool in South African Construction Projects

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## Abstract:

The construction industry has consistently proven itself to be one of the most challenging and dynamic fields of professional practice. General business activities and risk are inseparable; therefore, risk management has grown as a function and component of standard business operations. Insurance is an agreement where losses that are incurred by a few parties are shared with many others who may be susceptible to similar risks. This study is aimed at appraising the efficiency of insurance schemes as a risk management tool in the South African construction industry. To achieve this, a quantitative research method was used, and a structured questionnaire was designed to gather primary data for the study. The target population was contractors, government construction officials, consultants, and insurance organisations. The choice of these respondents was premised on the fact that insurance administration is a subjective task that is not part of the industry's core functions, therefore only selected individuals in the industry get the opportunity to be involved directly. Statistical tools such as Descriptive statistics, Mean Item score, and Kruskal-Wallis non-parametric test was used in analysing retrieved data. It was observed from the findings that insurance use in the construction industry is efficient in managing external risks, financial challenges, and health & safety. It was concluded that insurance can be used as a risk management tool for managing external risks, financial challenges, and health & safety risks.

**Keywords:** construction industry; insurance; risk management; risk mitigation

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## 1. Introduction

All over the world, the construction industry has consistently proven itself to be one of the most challenging and dynamic fields of professional practice (Zou, Zhang, & Wang, 2007). It has therefore gained notoriety as a sector that harbours the most potential for extreme risk by various means of evaluation (Babu & Kanchana, 2014). Ghahramanzadeh (2013) argues that the capacity of risk in this industry invariably out-weighs the potential carried by many other business sectors; therefore, it is paramount to introduce and continue to improve methods of dealing with risk. Often, risk prevention fails, which brings about the need for Insurance - among other methods of risk mitigation (Bunni, 2003). Much research has been conducted in order to identify and assess risks within the construction sector and as a result better understanding of these factors has been realised (Keçi & Mustafaraj, 2013; Rezakhani, 2012; Zou et al., 2007). The same, however, cannot be said for insurance, which is where this study derives relevance by seeking a deeper understanding and to further highlight what is



contextually relevant to the South African Construction Industry (SACI), while considering any other related knowledge gaps that may exist. While the knowledge gathered on construction project risks is valid, most of what is known failed to earnestly discuss the specific part that insurance plays within construction projects. Although, the account of risk and its factors are by no means exhaustive, it is undeniable that high levels of risk mitigation are necessitated (Keçi & Mustafaraj, 2013; Rezakhani, 2012). One of such risk mitigation strategy is insurance.

The most notably comprehensive insurance cover policy is referred to as Contractor's All Risks insurance (CAR) (Musundire & Aigbavboa, 2015), and due to its far-reaching nature, this body of work is largely based on it. Workers Compensation Insurance (WCI) is a version of insurance that protects lost wages and medical treatment for all work-related illnesses or injuries. Risks and disputes are part and parcel of business, however, the construction industry itself presents increasingly complex challenges, due to the processes and magnitude of contemporary projects. Great losses can be incurred due to risks, and the traditional method of self-insuring is no longer perceived to be practical from an economic standpoint. Other methods of dispute resolution, such as court proceedings are also no longer popular, not only because they are costly, but they are also thoroughly time-consuming (Song, Peña-Mora, Menassa, & Arboleda, 2011).

## **2. Literature Review**

Insurance is described as a means by which casualties incurred by a smaller party are compensated through funds gathered from those who are mutually insured. Financial loss that has resulted from an insured risk, is reimbursed by the insurer (Kikwasi, 2011). Insurance is, therefore, a protection against the uncertain. In principle, insurance is an agreement where losses that are incurred by a few parties are shared with many others who may be susceptible to similar risks (Anderson & Brown, 2005). The insurer is the company that offers insurance protection, while the insured is the party that buys it. Those parties who have the intention to obtain protection against particular risks pay a relatively low amount of money, often in regular premiums, to an insurance facilitating organisation in return for the insurance cover (Anderson & Brown, 2005).

### *2.1. Risks Associated with the South African Construction Industry*

According to (Dey, 2002), risk is a situation that involves exposure to the probability of financial or economic danger, gain or loss, injury or damage due to uncertainties. General business activities and risk are inseparable; therefore, risk management has grown as a function and component of standard business operations (Apostolik, Donohue, & Went, 2009). Risk management involves the different processes involved in limiting, controlling and sharing of risk instead of simply transferring the effects to another party. It is therefore, a typically structured process that facilitates the decisions to reduce both the effects and likelihood of associated risk (Broome, 2009; Bunni, 2003; Liu, City, Li, & Byrd, 2004). Systematic identification of where uncertainties originate, assessment of effects and probability of occurrence are carried out in order to realise a plausible balance between risk and more favourable positions (Harrington & Niehaus, 1999). Kerzner (2001) opined that formal methods of risk management include identification, analysis, planning, assessment, monitoring, and

handling. The standard process structure begins with identifying types and sources of risk, which is followed by a classification of risk by types of hazard and its effects. Next up is the evaluation of outcomes through various assessment techniques, which is followed by that specific organisation's decision regarding risk handling and finally, the actual response on how to manage the risk at hand. The risk response can either be to transfer it, to retain it, reduce it or even to avoid it. Insurance is one of three sub-components of the 'risk transfer' category. Construction companies deal with risk transfer in three different ways. These official avenues for risk transfer are the use of insurance, contract modifications and subcontracting. Insurance remains the most widely used method, thanks to its efficiency and reduced likelihood of creating additional problems, although this is not to say it is without its own faults (Odeyinka, 2000).

Key project risks have direct influence over insurance usage or have indirect influence through impacting overall profitability. Overall profitability can determine an organisation's ability and willingness to implement risk management strategies which bring about the need for a considered account of the risks that are of significant consequence in the construction sector (Bunni, 2003). Today, the function of insurance goes beyond assisting in risk mitigation for contractors. Insurers in the construction industry are also burdened with helping clients through risk identification, analysis and providing advice on how to reduce the likelihood of these risks. This improved efficiency of insurance in risk mitigation can, unfortunately, lead to complacency as some industry participants advocate transferring the entire risk management component to insurers. It is therefore paramount to discourage people from adopting this notion as it is terribly ill-informed. Insurance should not even be considered as an alternative to any safety program as it does not directly address hazards but can only be a last resort in response to loss occurrence. It is not the role of insurance to eliminate risk or moderate unsafe work practices, which are incidentally the major sources of losses (Liu et al., 2004).

According to Riddel (2017), risks in the SACI includes: Change in legislation; Physical risks; Environmental factors; Designing; Logistics; Financial; Construction Issues/ overruns. Ultimately, risk management is a collective effort by different parties to realise a common goal which is to reduce overall project risk. The main reason for this is to maintain control of projects objectives, which are to successfully complete projects without exceeding the prescribed budgetary parameters (Dey, 2002).

### **3. Research Methodology**

A quantitative approach to data collection took precedence as it is an effective way to achieve the aim and objective of this research work. Both primary and secondary sources of data were used albeit differently. The main primary source of data is the use of a well-structured questionnaire, while secondary information has been obtained largely from reviewing existing related literature and other relevant articles. The population used for this research study include construction industry professionals such as Architects, Engineers, and Quantity Surveyors, however, with prioritization for senior-level managers as they are more likely to know about insurance. Insurance industry employees such as agents and managers were also part of the population for the study provided that they have some construction related experience, with prioritization of individuals who have worked with CAR insurance. This inclusion of diverse

professionals is key to getting a truer reflection of results since the industry itself is comprised of diverse participants. A total of 65 copies were distributed, with 47 responses retrieved and found suitable for analysis. The questionnaire was designed using closed-ended questions to retrieve respondents' opinion on the efficiency of insurance as a risk management tool in the South African construction industry. The questions adopted 5-point Likert scale for ranking the variables. The scope of the research is limited to Johannesburg with most of the respondents (approximately 94%) accessed in Gauteng province. Purposive sampling was used as insurance administration is a subjective task that is not part of the industry's core functions, therefore only selected individuals in the industry get the opportunity to be involved directly. Statistical tools such as Descriptive statistics, Mean Item score, and Kruskal-Wallis non-parametric test was used in analysing retrieved data.

**4. Findings and Discussions**

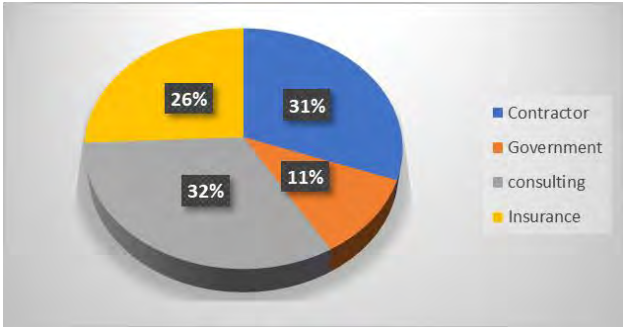


Figure 1. Category of respondent's organisation

From figure 1 above, the study shows that 31% of the respondents either work for or work as contractors with government workers constituting 11% of the respondent's population and various construction industry consultants made up 32% of the collective. People who work with the construction industry from the insurance organisation end made up the remaining 26% of the total group of respondents.

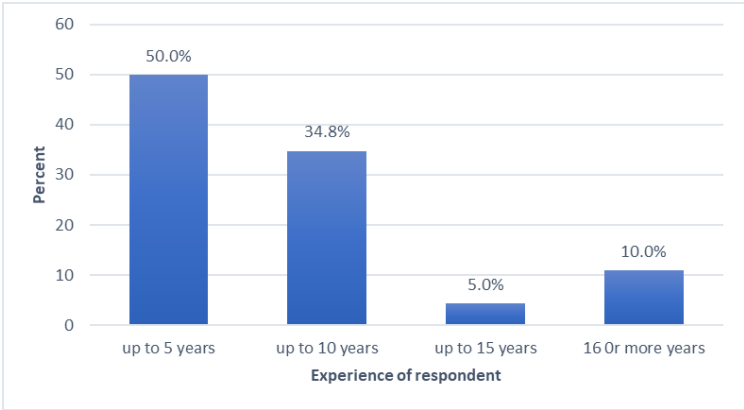


Figure 2. Years of experience of respondent's

Figure 2 indicated that 50% of the respondents have construction-related work experience that ranges from 1 to 5 years, while 34.8% of the same group have work experience ranging between 6 to 10 years. Only 5.0% of the population had between 11 to 15 years of experience,

while 10.0% of the respondents had worked in the construction industry for at least 16 years or even longer.

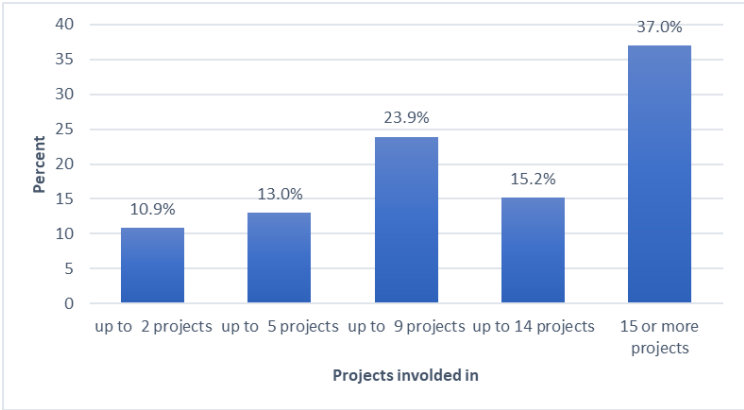


Figure 3. Number of projects respondents have been involved in

From figure 3 above, only 10.9% of the respondents have the limited experience of working on 2 projects or less, while 13.0% of those people have worked in the region of 3 to 5 projects in total. 23.9% of the group have participated in about 6 to 9 projects, while 15.2% of respondents have participated in between 10 to 14 projects. 37.0% of the respondents have been able to get involved in about 15 or more construction projects. With the background information of the respondents, it is obvious they have the required expertise to provide a reliable opinion about the efficiency of insurance as a risk management tool in the South African construction industry.

Table 1 shows the efficiency of insurance as a risk management tool according to the rankings of the respondents. The Kruskal-Wallis Asymp. Sig. values are all above 0.05 indicating that there are no statistically significant differences in the opinions of the different category of respondents on the efficiencies of insurance as a risk management tool. The higher the Kruskal-Wallis Asymp. Sig. value, the smaller the difference in the opinion of each category of respondents to the other. Respondents are of the opinion that construction insurance is best useful at helping mitigate external risks. Such risks include losses that cannot typically be controlled by people or organisations such as damage caused by natural disasters. At first rank, the mean stands at 3.80, which is slightly short of scoring ‘high’ according to the 5-point Likert scale measure. This indicated that when adequate insurance cover is made for a construction project and external risks arise, the construction project can still be completed without encountering deviation from the set project objectives and budget.

Table 1. Efficiency of Insurance as a risk management tool

Efficiency of Insurance	MIS	Chi-Square		Rank
		Value	Asymp. Sig.	
Efficiency at managing External Risks	3.80	1.77	0.62	1
Efficiency at managing Financial Challenges	3.50	7.08	0.07	2
Efficiency at managing Health & Safety	3.36	5.14	0.16	3
Efficiency at managing Overruns	2.93	2.36	0.50	4
Efficiency at managing transgressing Legislation	2.93	3.07	0.38	4
Efficiency at managing Design issues	2.91	0.47	0.93	6
Efficiency at managing Logistic problems	2.80	3.82	0.28	7

This findings agrees with the submission of Musundire and Aigbavboa (2015) indicating that CAR insurance is efficient in protecting the client and contractor's interest on construction projects. With a mean score of 3.50, insurance is considered to be efficient at mitigating financial challenges such that construction projects can be executed successfully even if the client/contractor encounter financial challenges during the execution of the project as long as there is an insurance cover for the construction project. This factor also has the lowest Kruskal-Wallis Asymp. Sig. value of 0.07 showing a high consensus of the respondent categories and also agrees with the findings of Musundire and Aigbavboa (2015). Respondents are of the opinion that insurance has the ability to mitigate health and safety risks on construction site having ranked it third with a mean item score of 3.36. Health and safety of workers on site is one of the major insurance cover clauses included in construction projects to ensure life of workers are secured. This is in tandem with the research work of Liu *et al.*, (2004) who opined that insurance covers for employer's liability/workmen's compensation and helps in health and safety management. A mean score of 2.93 places efficiency of insurance to manage both time and cost overruns on a construction site at joint fourth place with efficiency at managing organisation's legislative transgression. The MIS is slightly below the average value of 3.00 which is an indication that insurance cannot adequately manage these risks if encountered on a construction project. The efficiency of insurance at managing design issues ranked sixth according to the respondents which confirm that insurance is not very good at managing such risks. The Kruskal-Wallis Asymp. Sig. value of 0.93 is the highest among the seven factors which indicates a high conflicting view from the different categories of respondents on this opinion. Respondents also share the opinion that insurance fails the most at helping to manage logistic problems on construction projects.

## 5. Conclusion and Recommendation

It is concluded from the findings of this study that insurance can be used effectively and efficiently as a risk management tool for managing external risks, financial challenges, and health & safety risks. This will give contractors and the client rest of mind when it comes to managing risks on construction projects. This study, therefore, recommends that risks

associated with a construction project must be adequately evaluated before the final budget is made. This will give room for making necessary insurance cover for the construction project. Construction organisations are also advised to see the need to make use of insurance as a risk management tool. A further study can be carried out to investigate the extent to which insurance is used on construction projects within the South African Construction Industry.

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# Managing Construction Stakeholders in South Africa – The Construction Professionals’ Perspective

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## Abstract:

This paper presents the result of a preliminary study conducted to investigate the stakeholder management (SM) practices being adopted within the South African construction industry (SACI) and the possible measures needed for proper SM. This was done with a view towards achieving better stakeholder satisfaction on construction projects delivered within the SACI. A survey design was adopted with the questionnaire used to solicit quantitative data from construction professionals practicing in Gauteng province. In analysing the data gathered, percentage, mean item score, standard deviation, and one-sample t-test were adopted. The findings of the study revealed that in terms of the approach towards managing stakeholders, more emphasis is placed on monitoring and engagement of stakeholders than their identification. This approach can impact negatively on the proper management of stakeholders within the SACI as there is the need to adequately identify stakeholders from the onset of a project. Thus, to improve SM within the SACI there is the need to explore the needs and limitations of the stakeholders in a project and understand what interest them. It is equally important to define the project mission and formulate appropriate project delivery strategies. Although the result presented in this paper is the preliminary findings of a much larger research, it adds significantly to existing knowledge in terms of the important measures needed for proper SM and the attainment of stakeholders’ satisfaction within the SACI.

*Keywords:* construction professionals; drivers; stakeholder management; project success

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## 1. Introduction

All over the world, the construction industry has been termed as a challenging industry due to its complex and dynamic nature. This dynamic nature of the industry is believed to be the aftermath of uncertainties in technology, budgets, and development processes. However, despite these challenges, the industry still plays a major role in the development and achievement of the goals of society (Chan *et al.*, 2004; Navon, 2005). The complex nature of the construction industry has been associated with the fact that the industry contains many parties who are regarded as stakeholders (Enshassi *et al.*, 2009). According to Hammad (2013), the obvious importance of the industry to other sectors of the economy has brought about the presence of different stakeholders in the delivery of construction projects. These stakeholder’s interest varies and therefore needs to be managed accordingly.

In the past, project success was evaluated using the trio of time, cost and quality. However, in recent times, other performance measurement yardstick has evolved. Measures such as stakeholders’ satisfaction, customers benefit, and the likes have been observed over time.



Atkinson *et al.* (1997) noted the importance of incorporating the success of the stakeholders, evaluating their contributions and understanding their expectations in determining project success. Oliver and Rowlinson (2010) further solidified these assertions by stating that as project objectives differ so does the factors influencing their success. Similarly, the perception of the project stakeholders differs in terms of what constitutes success. Olander (2007) has earlier described a stakeholder as “a person or group of people with a vested interest in the success of a project and the environment within which the project operates”. Therefore, creating a way to effectively manage the relationship between the project and its stakeholders is crucial if success in a construction project is to be well defined (Yu and Shen, 2005).

There is no gainsaying that many stakeholders within a construction project is bound to bring with it some amount of disagreement among participants. This disagreement will most likely affect the project adversely. According to Hammad (2013), these disagreements among stakeholders are often because of poor identification and management of the different stakeholders involved in a project. Thus, identifying and recognising the stakeholders’ influence on successful project delivery is important to plan and execute sufficiently rigorous stakeholder management (SM) process (Olander and Landin 2005). Although the importance of SM in construction projects has been reiterated by several researchers (Newcombe, 2003; Olander and Landin, 2005), poor record of SM is still evident within the construction industry of most developing countries around the world, and the South African Construction Industry (SACI) is no exception. This unhealthy situation is evident in the poor and unsatisfactory project delivery being experienced in the country (Emuze and Smallwood, 2011). Thus, if a successful project is to be achieved through effective stakeholder’s management, identifying the stakeholders to a project is imperative. It is also important to ascertain their requirements and expectation and manage their influence in relation to the determined requirements (Othman and Abdellatif, 2011). It is based on this knowledge that this study, assessed SM approaches used within the SACI and the possible measures needed for proper SM. This was done with a view towards improving SM within the country’s construction industry and by so doing increasing the delivery of successful projects that meet stakeholder’s specifications. The subsequent parts of this paper show the review of existing literature, the methodology uses, the findings and conclusions drawn from the findings. Based on the conclusion, recommendations were made.

## **2. Stakeholder Management in Construction**

Freeman (1984) defined the term ‘stakeholder’ as “any group or individual who can affect or be affected by the achievement of an organisation’s objectives”. Following this definition, Newcombe (2003) defined a stakeholder with respect to the construction project as those individuals with a keen interest in the success of a project. Olander (2007) further affirmed this by stating that a project stakeholder is any person or group of persons with a significant interest in the successful completion of a project and subsequent development of the environment wherein the project is being carried out. Newcombe (2003) gave examples of these stakeholders in relation to a construction project to include “clients, project managers, designers, subcontractors, suppliers, funding bodies, users and the community at large”. Thus, it can be said that construction project stakeholders can affect the accomplishment of a project or be

affected by it (Freeman, 1984), therefore, satisfying their needs is a key factor in determining project success (Turner, 1999; Smith *et al.*, 2001). Olander (2002) have also earlier noted that construction stakeholders include a large set of individuals or groups as they occur both within the industry and the project environment. These set of individuals are affected either positively or negatively by the project. These effects can range from effective communication among stakeholders and a better standard of living for people within the project environment to negative construction impact on the physical environment such as deterioration and depletion of the environment's resources.

In classifying project stakeholders, Atkin and Skitmore (2008) posited that project stakeholders can be related to a project wither from within or outside the organisation. Those from within have a direct influence on the decision-making process within the organisation, while those from outside are affected by the organisation's decisions. Similarly, Carroll and Buchholtz (2006) have earlier grouped stakeholders as contracted and uncontracted stakeholders. The contracted stakeholders have a contractual relationship and according to Savage *et al.* (1991) can make a claim based on the contractual relationships. The uncontracted stakeholders, on the other hand, can either influence the project or be affected by it even with the absence of a contractual relationship. Chinyio and Akintoye (2008) classified project stakeholders based on decision-making. It was stated that stakeholders can either be "supportive, neutral, or anti-supportive". Construction stakeholders according to Harris (2010) and Siriwardena *et al.* (2010) can be grouped as: clients, consultants, contractors, funding body/donor; non-governmental organisations, government, beneficiaries'/end users, the public, and local landowners/neighbourhood. Considering these large arrays of stakeholders, managing them effectively with a view towards attaining successful project becomes important. While management of stakeholder can be defined in varied forms, the key components are in most case the same. They are the key stakeholder management activities that need to be in place for effective stakeholder management. These are; stakeholders' identification, getting the right information on stakeholders, analysing their influence, communication, and developing strategies (Bourne and Walker, 2006; Karlsen, 2002). Therefore, stakeholder management is "the process of identification, analysis, communication, decision making and all other kinds of activities in terms of managing stakeholders" (Yang *et al.*, 2011).

According to Bourne and Weaver (2010), stakeholder management practices refers to the methods for selecting and managing the right stakeholders. These include: identifying; prioritising; visualising or mapping; engaging and; monitoring or managing. *Identifying stakeholders* is the starting point of stakeholder selection and it focuses or helps on defining different stakeholders to a project. Olander and Landin (2005) have earlier noted the importance of stakeholder identification from the onset of the project. Through this identification, the effect these stakeholders can have on the project (positive or negative) can be determined and these can be managed through effective communication. Ibrahim (2014), therefore, submitted that stakeholder identification involves knowing the different participants of a project whose role is geared towards successful completion of the project. Since not all stakeholders are the same, nor are they all affected by the project in the same way, *prioritising stakeholders* is therefore important. Nash and Chinyio (2010) stated that since most times it is difficult to satisfy the wish of all stakeholders, prioritisation helps in making the best possible decision in each situation.

Kolk and Pinkse (2007) noted that organisations can prioritise some stakeholders at the expense of others, thereby allowing the organisation to concentrate on a significant number of stakeholders at a time.

After prioritising stakeholders, it is important to develop a list that shows the different characteristics of the stakeholders. The list is geared towards helping the organisation in making a strategic decision regarding the management of the project stakeholders (Bourne and Weaver, 2010). This process of assessing the stakeholders base on their key characteristics is known as *visualising or mapping of stakeholders*. Common key characteristics which are looked out for are the power of the stakeholders, their support, influence, interest, attitude, and predictability. Next step is to engage these stakeholders in a bid to identify the key area of focus for the scarce available resources of the organisation and in attaining maximum project outcome. This process of *engaging stakeholders* is considered important if effective use of organisations resources is to be achieved (Bourne, 2010). Low and Cowton (2004) identified two (2) steps for engaging stakeholders. The first step involves meeting with the stakeholders to assess their view about the project while at the same time understanding that their level of influence on the corporate decision-making of the project at this stage is minimal. Secondly, a more inclusive stakeholder management approach is taken, thereby creating avenues for stakeholders to be involved in decision-making and integrating. The last step is *monitoring stakeholders* which involves managing the influence of the identified stakeholders on the project outcome. Since different stakeholders abound on every given project, there is the possibility of conflicts arising between them and this may be detrimental to the outcome of the project. Monitoring them will, therefore, help in predicting these conflicts before they occur and solving them early. This is mostly done through effective communication. It is necessary to have a specific communication strategy that is designed for the project stakeholder community (Bourne, 2010).

### **3. Research Methodology**

This study assessed the management of stakeholders within the SACI through a preliminary evaluation of the SM approaches being adopted within the industry as well as the possible measures needed for their proper adoption. A survey design was adopted for the study and quantitative data was gathered from construction professionals (Architects, Engineers, Quantity Surveyors, and Construction managers) practising in Gauteng province using a structured questionnaire. A total of 58 construction professionals participated in the study. The questionnaire used was designed based on the findings from the review of existing literature on the subject under study. The choice of using a questionnaire was because the questionnaire has been adjudged to be easiest and most widely used research instrument in most social researches and it has the ability to cover a wide range of respondents (Blaxter *et al.*, 2001; Tan, 2011). The questionnaire was designed in sections with the first section designed to gather information on the respondent's background. The second section gathered information regarding the SM approaches being adopted and the possible drivers needed for their proper adoption. A 5-point Likert scale was employed with 5 being very high adoption/significance, and 1 being very low adoption /significance. The average was set at 3. Data analyses were done using percentage for data on the background information of the respondents. Mean Item score (MIS) and standard deviation (SD) were used to rank the identified variables based on their rating with the highest

mean value ranking first. However, where two variables have the same mean value the one with the lowest standard deviation was ranked first as suggested by Field (2005). Furthermore, a one-sample t-test was further used to identify the level of significance attached to the identified variables. The reliability of the questions in this second section was also tested using Cronbach's alpha test which gave an alpha value of 0.933 and 0.937 for both the adoption of SM approaches and the drivers. This implies that the questionnaire used was reliable.

## 4. Findings and Discussions

### 4.1 Background information

Analysis of respondent's background information revealed that 16% were architects, 24% were engineers, 32% were quantity surveyors, and 28% were construction managers. Majority of these respondents (71%) have above 5 years working experience within the built environment, while only 29% have below 5 years of working experience. The average years of working experience of the respondents are calculated as 10.1 years which shows that the respondents for the study have significant experience within the built environment to give reasonable answers to the question of the research. Also, the respondents for the study are considered educated enough as the majority of them have a Bachelor's degree (44%), while 28%, 20%, and 8% have a National Diploma, Master Degree, and a Higher Certificate respectively.

### 4.2 Stakeholder Management Practices adopted in the South African Construction Industry

The result in Table 1 shows the different SM practices assessed, their mean value and standard deviation, as well as their t-value and significant p-value derived from one-sample t-test conducted. From the table, it is evident that all the assessed SM practices are being adopted as they all have a mean value of the above average of 3.0. Similarly, one-sample t-test revealed that the respondents consider these identified SM practices significant as a significant p-value of less than 0.05 was derived for all assessed variables. From the table the most adopted SM practices are monitoring stakeholders (*mean* = 3.84, *sig.* = 0.000), engaging stakeholders (*mean* = 3.78, *sig.* = 0.000), and prioritising stakeholder (*mean* = 3.55, *sig.* = 0.000). Lesser consideration is placed on the identification of stakeholders as it was ranked the least with a mean value of 3.34 and a significant p-value of 0.007.

From the above result it can be concluded that base on construction professionals' perspectives, adequate attention is given to the monitoring, engaging and prioritising of stakeholders within the SACI. However, the first major practice towards effective management of stakeholders which is their identification is given less attention. Othman *and* Abdellatif (2011) have earlier mentioned that for a project to be adjudged successful specifically with relation to stakeholder's satisfaction, the project team must identify the stakeholders of the project and sufficiently define their expectations. Only after identifying these stakeholders can other practices such as prioritising them, mapping them, engaging them and then monitoring or managing them as observed by Bourne and Walker (2006) be achieved. Findings of this study are in line with the submission of Ibrahim (2014) which shows that not all the stakeholder management activities are taken into consideration is stakeholder management of most

construction projects. Thus, if effective project delivery is to be achieved through stakeholder management, then thorough consideration must be given to the whole stakeholder management practices. Seeing the stakeholder management approach as a holistic management approach rather than piecemeal help the delivery of a successful project achieved through proper stakeholder management.

Table 1: Stakeholders management practices adopted in the SACI

SM Approaches	Mean	SD	Rank	One-sample t-test	
				t	Sig. (1-tailed)
Monitoring stakeholders	3.84	1.225	1	5.250	0.000
Engaging stakeholders	3.78	1.257	2	4.700	0.000
Prioritising stakeholders	3.55	1.111	3	3.782	0.000
Mapping of stakeholders	3.48	1.080	4	3.404	0.000
Identification of stakeholders	3.34	1.035	5	2.536	0.007

#### 4.3 Measures for Improving Stakeholder Management in the South African Construction Industry

The result in Table 2 shows the ranking of the possible measures for SM improvement as rated by the respondents. Based on the review of related literature, some measures were identified, and respondents were asked to rate these measures based on their level of significance using a 5-point scale. The table shows the mean value of the different identified measures, their standard deviation, t-value and significant p-value derived from one-sample t-test conducted. A cursory look at the table shows that all the assessed measures have a mean value of above average of 3.0. This implies that to a considerable extent these measures if implemented can help ensure proper SM within the SACI. Similarly, one-sample t-test revealed that the respondents consider these identified measures to be significant to the proper adoption of SM as a significant p-value of less than 0.05 was derived for all assessed variables. Chief of these measures are exploring stakeholders' needs and constraints in projects (*mean = 4.38, sig. = 0.000*), understanding the area of stakeholders' interests (*mean = 4.10, sig. = 0.000*), defining project missions (*mean = 4.1, sig. = 0.000*), formulating appropriate strategies for the delivery of the project (*mean = 4.09, sig. = 0.000*), and assessing stakeholder's behaviour (*mean = 4.05, sig. = 0.000*), and assessing stakeholders attributes (*mean = 4.02, sig. = 0.000*).

From the findings, it is evident that for SM to improve within the SACI, there is the need to properly explore stakeholders needs and understand their area of interest. By so doing, the

right approach towards satisfying the needs and interest of these stakeholders can be adopted as observed by Smith *et al.* (2001) and Tuner (1999). This is in line with Yang *et al.*, (2009) submission which stated that one of the key ways of attaining success in the management of stakeholder is through identifying stakeholders properly, the understanding area of stakeholders' interests, as well as exploring stakeholders' needs and constraints to the project. From the result, it is also evident that there is a need to adequately define the mission of the project and formulate appropriate strategies that will aid the attainment of the defined mission of the project. This is a vital role for the project manager whose role in the successful management of stakeholders have been observed in past studies (Newcombe, 2003; Olander and Landin, 2005; Chinyio and Akintoye, 2008; Ibrahim, 2014). It is also important for the project manager or the project team to carefully assess the behaviour and attributes of the identified stakeholders as this might influence the outcome of the project positively or negatively. A similar observation was made by Hammad (2013). This finding also corroborates Savage *et al.*, (1991) submission that the capacity and willingness of stakeholders to threaten or cooperate with project teams should be measured during the stakeholder management process. This is because, stakeholders may have negative or positive impacts on projects, hence the need to determine objectors and supporters.

Table 2: Measures for improving stakeholder management in the SACI

Measures	Mean	SD	Rank	One-sample t-test	
				t	Sig. (1-tailed)
Explore stakeholders' needs	4.38	0.895	1	11.737	0.000
Understand stakeholders' interests	4.10	0.986	2	8.526	0.000
Define project missions	4.10	1.224	3	6.866	0.000
Formulate required strategies	4.09	1.159	4	7.137	0.000
Assess stakeholder's behaviour	4.05	1.042	5	7.624	0.000
Assess stakeholder's attributes	4.02	1.110	6	6.922	0.000
Predict stakeholders' reactions	3.97	1.256	7	5.587	0.000
Manage conflicts effectively	3.95	1.248	8	5.785	0.000
Analyse conflicts and coalitions among stakeholders	3.90	1.224	9	5.579	0.000
Undertake cooperate social responsibilities	3.88	0.880	10	7.609	0.000
Predict stakeholder's influence	3.84	1.152	11	5.854	0.000
Ensure effective communication	3.78	1.185	12	4.985	0.000
Analyse stakeholder's changes	3.59	1.229	13	3.633	0.000
Promote good relationship	3.43	1.110	14	2.957	0.003

## 5. Conclusion

This study through a preliminary study assessed SM practices used within the SACI and the possible measures needed for proper SM. Information was gathered from construction professionals and based on the findings from the analyses conducted, the following conclusions were drawn. The most common approaches used in managing stakeholders are monitoring stakeholders, engaging stakeholders and prioritising stakeholder with lesser consideration given to the identification of stakeholders. This neglect of stakeholders' identification can impact negatively on the proper management of stakeholders within the SACI as there is the need to adequately identify stakeholders from the onset of a project. Therefore, for improved SM to be attained within the SACI, certain measures need to be put in place. These include: exploring stakeholders' needs and constraints in projects, understanding the area of stakeholders' interests, defining project missions, formulating appropriate strategies for the delivery of the project, and assessing stakeholder's behaviour and attributes. Although these findings are the preliminary findings of a much larger research, it contributes to the body of knowledge as it brings to light some important measures needed for proper SM and the attainment of stakeholders' satisfaction within the SACI. However, care must be taken in generalising the result of the study as the study was limited to a single province within the country. There is a need for further studies in other provinces within the country, to compare results.

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# Time Analysis of Networks with Bi-directional Precedence Relationships: A Case Study

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## Abstract:

Recently 99% of projects are scheduled with traditional Precedence Diagramming Method (PDM) in order to calculate the project duration and the early and late starts/finishes of activities. During the decades the modelling capabilities of the method have not been improved: activities were handled as linear and continuous and the four precedence relationships (FS, SS, FF and SF) were used to describe the logic between activities. Recently, new developments were added to the original model to extend the modeling capabilities of the PDM such as point-to-point and continuous precedence relationships and relationships with AND/OR Boolean operators or bi-directional relationships. Among these relationships, calculations with AND/OR Boolean operators are extremely demanding and the application of them soon can lead to the so-called combinatorial explosion. Time analysis with bi-directional relationships leads to the same problem since they are replaced by two OR relationships when preparing for time analysis. The main goal of this research is to check if existing algorithms for relationships with Boolean operators and bi-directional relationships can be used in real life construction projects. A logic that contains 9! different scenarios in one project dataset were developed and tested for running speed.

Results show that the running time of the algorithm depends more on the number of scenarios (i.e. the number of OR and bi-directional relationships) than the size of the network. Therefore, above a certain size of scenarios the running time dramatically increases and there is a need for faster algorithms or heuristics.

*Keywords:* critical path method; precedence diagramming method; and/or boolean relationships; bi-directional relationships;

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## 1. Introduction

Finding the optimal project duration in repetitive projects is a well-known, but not deeply investigated problem due to the limitations of the existing project planning techniques like Linear Scheduling Method (LSM) and different network scheduling techniques. The problem can easily be understood based on the following simple, artificially created problem.

There are two pipelines to build in two adjacent parallel streets (street #1, street #2). Activities are the same in each street, but durations are different due to the different geometrical and soil conditions. This is summarized in Table 1.

Table 1. Duration of activities on both streets in days

	Street #1	Street #2
Asphalt removal	1 day	1 day
Excavation	4 days	1 days
Pipe-laying	3 days	3 days

For the sake of simplicity let us assume that pipe laying (act C) follows earthwork (B) by three days safety distance and the same logic exist between earthwork (B) and asphalt removal (A). The three days safety distance prescribes that at least three days must elapse after the predecessor activity leaves a certain section of the street before the successor arrives to the same section. This could be modeled: a) in LSM techniques using a three-day time buffer between activities A and B and between activities B and C; b) in traditional Precedence Diagramming Method (PDM) as the combination of SS3days and FF3days precedence relationships between activities A and B, and between activities B and C; or c) defining the recently developed continuous relationships of PDM by using 3days lags between act A and B and between B and C. The logic expressed by these three methods for street #1 can be seen on Fig 1.

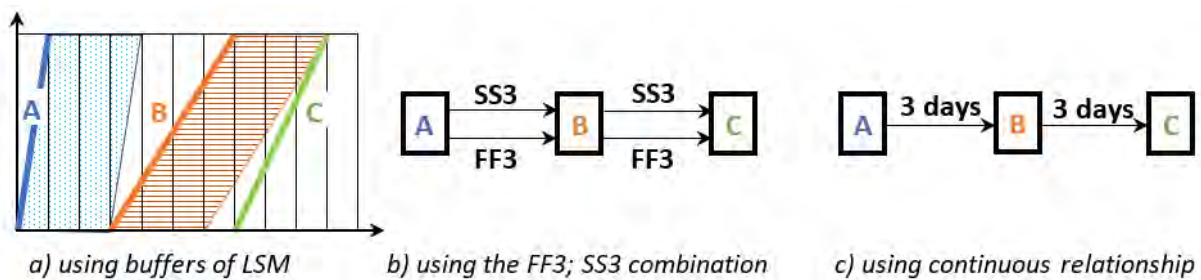


Figure 1. Interpreting the logic between activities on street #1

The application of continuous relationships is quite new in network planning, they can be interpreted as the network planning equivalents of the buffers of LSM therefore they can be applied for non-linear activities too. (Hajdu 2015a), (Hajdu 2016).

Let us assume that there are specialized teams for all activities, one for asphalt removal (team A), one for earthwork (team B) and one for pipe laying (team C). This means that similar activities cannot be executed at a same time in different streets. A possible LSM representation and its PDM network technique representation using continuous precedence relationships can be seen on Fig 2.

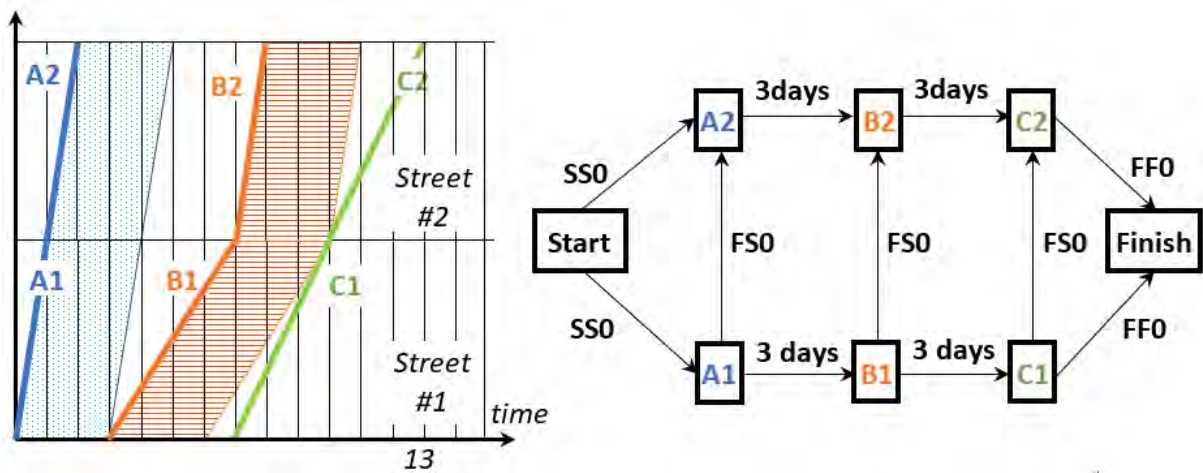


Figure 2. LSM and PDM representation of the sample project, Sequence of streets: street #1 – street #2

The project duration is 13 days and all teams can work continuously without interruption. However, we come to another solution if the work starts on street #2 for each types of activities. The LSM and PDM interpretation of this solution can be followed on Fig 3.

This sequence provides a shorter project duration by one day therefore this must be selected. Following this line of thought in case of three streets there are six possible cases to examine (1-2-3; 1-3-2; 2-1-3; 2-3-1; 3-1-2; 3-2-1) and in case of  $n$  streets there are  $n!$  possible arrangements among the streets. Computation effort of producing all the possible sequences very soon leads to the so-called combinatorial explosion as the number of streets increases. Assuming 15 streets in a project and a computer that can check one million possible sequences in a second the computation time would be 15 days.

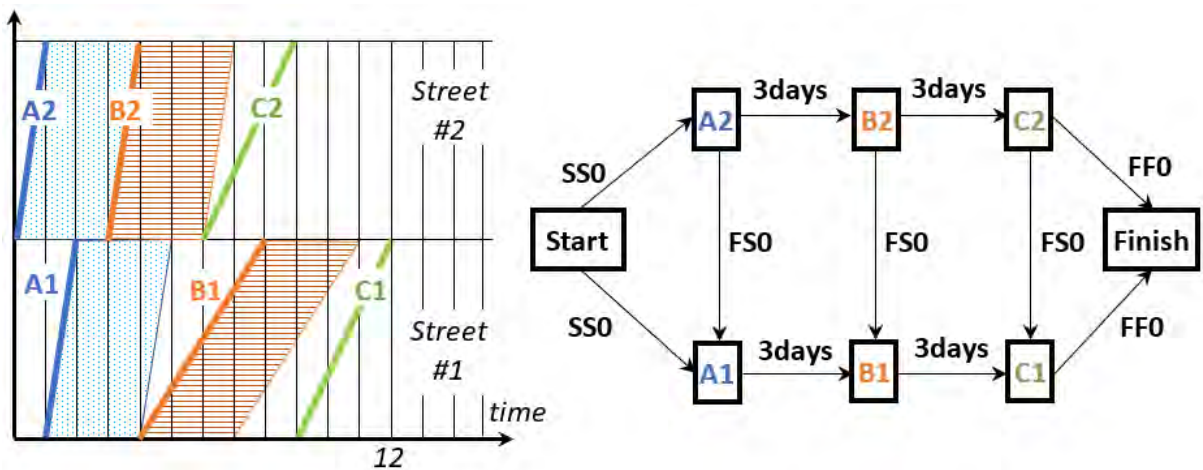


Figure 3. LSM and PDM representation of the sample project. Sequence of streets: street #2 – street #1

Unfortunately checking all the sequences of streets and selecting the one with the least project duration does not necessarily provides the optimal solution. Fig. 4 shows a situation that supports this statement. The reader must observe that in this case buffers are not the same. Sequence street #1 - street #2 leads to 13 days of project duration, sequence street #2- street #1 leads to 11 days of project duration, however the project duration is only 10 days if A2 is executed after A1, but B2 and C2 are executed before B1 and C1.

This leads to a conclusion that in case of two streets with three activities there are 6 possibilities, in case of three streets there are  $6*6*6=216$ , and in case of  $n$  streets and  $m$  different similar activities (with just one specialized team for each activity type) the number of possible arrangements is  $(n!)^m$ . Finding the shortest project duration by making a complete enumeration using the above mentioned computer and algorithm the computational time would be 34 days in case of five streets and six similar activities which is shockingly long for such a seemingly small project.

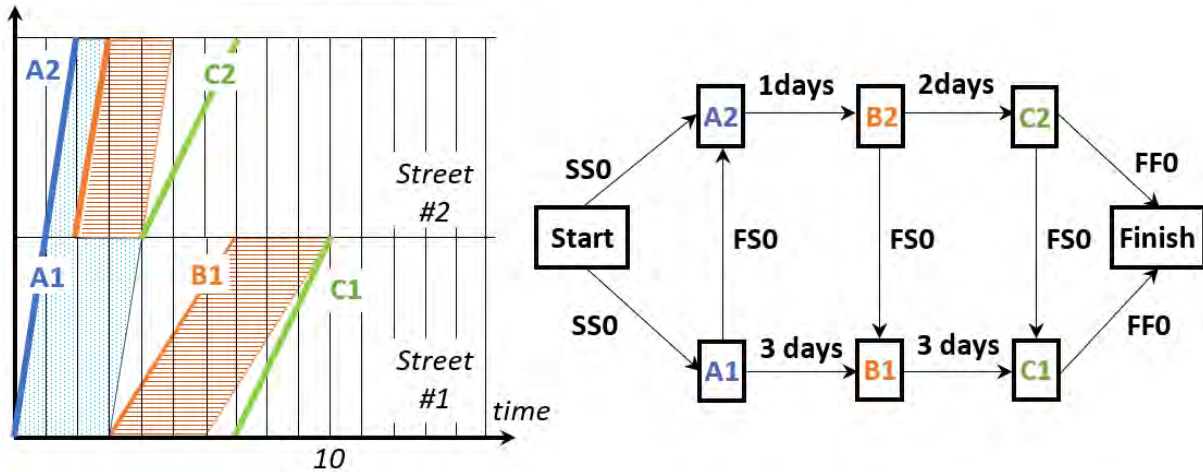


Figure 4. LSM and PDM representation of the sample project. Teams work in different sequence

There are many repetitive projects especially linear projects in the construction industry where considerations finding the optimal sequence would be useful. Although potentials for saving time in these types of repetitive projects are huge, planners usually do not apply any techniques in order to find the optimal sequence. There could be many reasons for this but probably the static nature of the existing planning techniques plays the major role in this. Under the term of ‘static nature’ we understand that these models can handle only one possible logical system of a project and every new sequence requires a creation of a new version of the project logic through some tiresome modifications. Creating such a huge number of different project versions is beyond the work that one can expect from any project planner.

Recently developed bi-directional relationships and relationships with Boolean OR and AND operators (Hajdu 2018) can help in modeling the different logic in one logical plan. According to Hajdu a bi-directional e.g. FS0 relationship between activity A and activity B can be interpreted as either B follows A or A follows B, but they cannot overlap. The logic that shows all the 6 possibilities for the sample project by using bi-directional FS0 relationships can be seen on Fig 5.

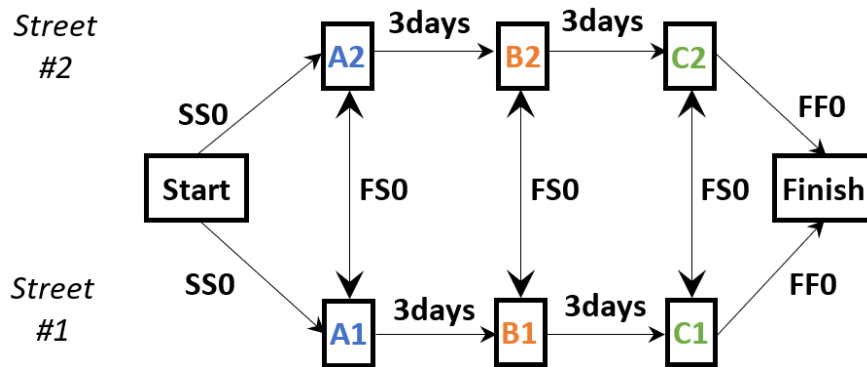


Figure 5. Modeling all the possible sequences with bi-directional relationships

The algorithm given by Hajdu (Hajdu 2018) converts all bi-directional relationships into two relationships with OR Boolean operators, from now on called as relationships with OR switches. After converting it systematically detects and performs time analysis for all the possible arrangements to find the sequence with the least project duration. This algorithm soon can lead to a combinatorial explosion. Hajdu has tested his algorithms only on small size networks and there is no experience with real life networks. The goal of this paper is to examine if real life networks can be solved by using Hajdu's algorithm or not.

## 2. Literature review

History of network techniques has started with the development of Critical Path Method (CPM) (Kelley & Walker 1959) (Kelley 1961) and with the development of Program Evaluation and Review Technique (PERT) (Malcolm et al 1959). Both developments have taken place in 1957. The former provided an optimal solution to the problem of finding the smallest direct cost solution to a given project duration also known today as the time-cost-trade-off problem, the later defined a stochastic problem with the goal of defining the distribution of the project duration assuming that the distribution of the duration of the activities are defined by the use of the so called PERT-Beta distribution. Both techniques were represented by activity-on arrow (AOA) graphs with one start and one finish nodes, where the arrows of the graphs represented the activities and the nodes represented the so-called events and the logic among the activities succeeding and preceding the events. This kind of logic can be defined based on PDM technique if only Finish-to-Start-zero-day relationships (FS0) were allowed both in CPM and PERT. The much more flexible PDM technique was developed in 1964 (IBM 1964). This technique was an activity-on-node (AON) network using the earlier results of Fondahl (Fondahl 1961) and defined an extended capability for modeling the logic between activities namely the Start-to-Start-z (SSz), the Finish-to-Start-z (FSz), and the Finish-to-Finish-z (FFz) precedence relationships. However, the developers failed to define the Start-to-Finish-z (SFz) relationship. The reason for this can be found in the original definition of the relationships.

According to the original work (IBM 1964) SSz was defined as that at least z day work on the predecessor must be finished before the start of the successor, and FFz was defined as at least z days of work must remain on the successor before the predecessor finishes (IBM 1964).

Following this logic, one would have difficulties how to divide the z relationship duration between the predecessor and the successor when defining a SFz relationship and this is the reason that only three precedence relationships were defined, and the developers have not defined SF relationships.

Today another interpretation is used for interpreting precedence relationships. According to this a SSz or FFz or SFz or FSz can be defined that at least z time has to elapse between the selected points (Start or Finish points) of the activities. During planning both interpretations of SSz and FFz lead to the same results in the course of time analysis, so vast majority of the planners do not know about these two different interpretations. However, they must be handled in different ways in the course of tracking. Let us imagine two activities (act. A and B) and an SS3 relationship between them. Let us assume that activity A started on the first day and after the second day it stopped. According to the original interpretation B cannot start as 3 days of work on A has to be finished before the start of B. If A does not start for a week then B cannot start either. According to the second interpretation B can start on the third day as the relationships tells that there must be at least three between the starts.

Parallel with these work a similar technique was developed in Europe by Roy (Roy 1959) the so called Metra Potential Method (MPM). Roy's technique was portrayed as an AoN network and were connected by minSSz and maxSSz relationships. (Maximal SSz relationships can be interpreted as maximum z time can be between the start of the predecessor and the start of the successor.)

The next important development regarding the fundamentals of the PDM technique was the development of the so-called Point-to-Point (PtP) relationships (Francis & Miresco 2000) (Francis & Miresco 2002). Point-to-point relationships define the minimum distance between any points of the activities. To define a point-to-point relationship, one must define the two internal points of the connected activities (one in each) and the necessary minimal lag between them. This can help to describe both the original and the recently used interpretations of SS and FF relationships. The original interpretation of SS3 can be modelled as a [three-day point, 0 day point, 0 day] or [three-day point, Start point, 0 day] relationship which tells that the two connected points are the three-day point on the predecessor and the start point of the successor, and the lag between them is zero day. The new interpretation can be defined using [0 day point, 0 day point, 3 days]. This can be seen on Fig. 6.



Figure 6. The original and the recent interpretations of the SS relationships using PtP relationships

The maximal type of the PtP relationships and the algorithm for time analysis was defined by Hajdu (Hajdu 2015b). Also, Hajdu used the Point-to-Point expression first (Hajdu 2015c) to

emphasize that these relationships connect one point of the predecessor with one point of the successor, meanwhile the continuous relationships define the same lag between all the corresponding points of the related activities. Continuous relationships that were used in the sample project to prescribe the safety distance between all the corresponding points like the buffers in LSM are the result of Hajdu (Hajdu 2015a) (Hajdu 2016). Interpretation of continuous relationships with time lag and work lag can be seen on Fig 7. The huge advantage of continuous relationships is that they can perfectly model the logic between overlapping activities. This makes the recalculation of the network based on monitoring data flawless. Another advantage of continuous relationships is that they can be used in case of non-linear activities as well.

Bi-directional relationships and relationships with Boolean logical operators such as AND or OR are the results of Hajdu (2018). Hajdu has pointed to the fact that a bi-directional relationship can be substituted by two relationships with OR Boolean switch, which referring to the sample project can be interpreted as either A on street #1 follows A on street #2, or A on street #2 follows A on street one. This type of conditional logic can be used to model different scenarios of the project in one model.

### **3. Goals and limitations**

It has been mentioned earlier that the time analysis in case of bi-directional relationships or relationships with OR switches is based on the time analysis for all the possible arrangements and this soon can lead to a combinatorial explosion.

The primary goal of this paper is to define whether the algorithm proposed by Hajdu is suitable for real life projects or not.

For the sake of simplicity calendars were eliminated from the project, resources were assumed to be unlimited, splitting and stretching of activities were not allowed for easier interpretation of results.

### **4. Methodology**

One real life project has been used for the purpose of this study. MS Project has been used for planning the original project therefore restrictions of MS Project had to be accepted. These were the followings:

- only minimal endpoint PtP relationships (i.e. SS, FF, SF and FS with time lag) can be used to define the logic between activities
- maximal precedence relationships are not allowed
- only one precedence relationship is allowed between two activities
- continuous relationships are not allowed

For the sake of simplicity calendars, constraints, resources were removed from the project file. It was found that in all the cases constraints were used to substitute some logic therefore these constraints have been replaced by relationships. Before adding the bi-directional



relationships modeling different sequences the project file included 895 activities. 675 of them were leaves of the WBS the rest of them were summary activities including the activity representing the project. The project was about to build nine new sewage pipes by leading them into the existing collector. The streets were divided into 50 meters sections due to the shoring capacity for trench protection. It was assumed that once the work on a street has been started at one end of the street the work must continue till the other end of the street. Shifts to non-consecutive sections or to different streets were not allowed before finishing the work on the given street.

New bi-directional FS0 relationships within the similar activities of the streets were used to model the conditional logic.

The algorithm has been written in C++ using MS Visual Studio and was run on a Lenovo 2.5MHZ laptop with 8MB RAM.

## **5. Results**

9! that is 362880 different arrangements for nine streets were checked by the algorithm. It was assumed that all teams work after the same sequence pattern. The computational time was less than two seconds on an average laptop. The smallest project duration was 234 days the largest was 284 days, which means that there is almost two months difference between the possible shortest and longest project duration.

The project was given to three experienced scheduler and they were asked to prepare a feasible plan under the same circumstances. WBS activity durations, logic within the street has been provided in an MS Project file. Their task was to describe the logic enforced by the fact that specialized teams must be used for similar activities, that is to add FS0 relationships among similar activities on different streets. Two out of three have built the network according to the most trivial sequence that is street #1- street #2- .....- street #9, which has resulted in a project duration of 262 days. One of them realized that different sequences of streets probably would have resulted in different project duration but realizing this took too much time and within the five-hour time limit he was not able to deliver a feasible solution.

## **6. Conclusions and further research**

This one example is not enough to draw general conclusions about the benefits of using bi-directional and conditional logic. However, early results show that there are possible huge potentials in building different scenarios into a project dataset and letting the computer select the optimal i.e. the shortest project duration. However, in case of more streets or allowing different sequences for teams the method that systematically checks all the possible arrangements tends to be time consuming and there is a need for new methods in order to handle larger problems.

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# Re-Visiting the Impediments of Cost Contingency Plans for Construction Projects in South Africa

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## Abstract:

Construction projects require a budget plan that would sponsor the entire project and unforeseen circumstances that comes with the project. Cost contingency is a certain amount added to the actual contract amount to cater for the risks and uncertainties of the project's objectives. Aim of this study is to evaluate the method used in deriving the cost contingencies for construction projects and assess the factors affecting cost contingency plans for construction projects. Quantitative research method was adopted with questionnaire used as the research instrument for gathering information from Quantity Surveyors, Construction Managers, and Project Managers within Gauteng province, South Africa. Descriptive statistics, Mean Item Score, and Kruskal-Wallis H-test was used in analysing the data retrieved. The findings revealed that most construction project professionals use the deterministic method for deciding cost contingencies which are derived using a percentage of the base cost estimate of the construction project. It was also revealed that poor planning, poor estimates and lack of experience are the major factors affecting the efficacy of cost contingency plans for construction projects. The study concluded that proper planning and adequately prepared estimates based on sound experience of the project team will assist in making precise cost contingency planning for construction projects.

*Keywords: contingency; cost; project planning; risks; uncertainties*

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## 1. Introduction

In construction, there is a need to have a budget plan in order to set the sponsor's financial commitment. This budget plan serves as the basis for measurements of cost performance and gives necessary information for cost control on the construction projects. The project sponsor's key success criterion for construction projects is cost performance. Similarly, the key component of the project budget is cost contingency (Creedy, Skitmore, & Wong, 2010). Cost contingency according to Godfrey (1996) is a certain percentage of the project's cost added to the project total value to represent the commitment of a client for an unforeseen event that may arise during the construction phase of the project. In this way, the calculation of the percentage of cost contingencies is of critical significance to the project as well as its ultimate adequacy. Construction projects consist of three kinds of contingencies i.e. money in the budget, float in the schedule and tolerance in the specification. Although, contingencies are mostly misinterpreted, misunderstood, and misapplied in the execution of the projects (Patrascu, 1988). However, Project Management Institute (2013) defined contingency as the certain allowance in

the contract sum that is acceptable by the organization added to the actual project amount to cater for the risks and uncertainties within the project's objectives. By the reason of having cost contingency as part of the budget to reduce uncertainties and risks of overruns on the project, it may or may not include the reservation of management which cater for the non-planned but required changes in the scope of the project. During the construction process, changing factors and unexpected variables influence the process resulting from different sources which include external conditions, the performance of construction parties, managerial issues, financial issues and resource unavailability (Mahamid & Dmaid, 2013).

It was revealed in literature (Buertey, Abeere-inga, & Kumi, 2012; Enshassi & Ayyash, 2014; Nawar, Hosny, & Nassar, 2018; Polat & Duzcan, 2010; Smith & Bohn, 1999) that inadequate contingency allowances in the bid process may result in loss of tendering, unrealistic outcomes and/or significant overruns and losses at later stages of the project. However, the significant losses and/or uncontrollable impacts including financial aspects may arise from ignoring the possibility of uncertainties earlier and their impact on the project. With this phenomenon being a major drawback in the construction industry according to the submissions of Bello & Odusami (2009) and Eldosouky, Ibrahim, & Mohammed (2014), there is a need to take a careful look into the factors affecting it. This study, therefore, seeks to assess the impediments of Cost contingency planning on construction projects in the South Africa construction industry.

## **2. Literature Review**

Cost Contingency plans in a construction project, in general, allows for flexibility and effective responses to change orders and unforeseen risks (Bello & Odusami, 2009). In a construction project cost contingency planning, the size of the project must be the first consideration before looking at other factors. This will help the project team in establishing baselines for uncertainties within the project by defining both external and internal risks thereby providing appropriate measures (Johnson, 2018). Polat and Duzcan (2010) added that it will provide good structures to quantify, put risks first, identify and set the programme for the project while allocating resources. Polat and Duzcan (2010) further stressed that good contingency planning always has clear triggers for uncertainties in which triggers can be estimations and budget assumptions that are proven to be pointers. With the triggers in place, the project team can get the accurate and fast read on changing orders by closely keeping an eye on those factors linked to the triggers. Moreover, a good contingency plan requires the project team defining specific actions to fulfill bound conditions in a project (Spacey, 2017). Buertey et al., (2012) added that a contingency sum may not necessarily prevent the construction project from experiencing overrun in the case of unpredictable changes. This will warrant adjustments on costs or scope of the construction project. Below are some of the factors that affect the efficiency of cost contingency planning on construction projects:

### *2.1. Poor planning*

Before the project commences, the undertaking construction manager must guarantee that the project work is legally understood and agreed to by the management as well as key project sponsors (Skoyles & Skoyles, 1987). Polat and Duzcan (2010) added that the construction

manager together with the other project team need to work hand in hand to ensure that there is a proper plan which presents the completion period of the project, the total cost to be expended, steps in which the project will be carried out, possible advantages that will be available and an individual organisation that will be involved in executing significant parts of the construction project. Furthermore, the planning process and definition of scope must be completed before commencing the construction of project prerequisites. Inability to do so is termed poor planning (Polat & Duzcan, 2010).

### *2.2 Poor estimates*

Typically, the projects need a cost contingency plan together with deadlines. In most cases, when the definitions and planning are not completed earlier, the project team starts with deficient materials which are not mostly noticed until when the work has progressed. Most projects which can be regarded as effective at the planning phase end up being viewed as downcast when they spend more than expected with the due dates and financial plans. The above situation is often the result of the estimator estimating the quantities lower than required (Polat & Duzcan, 2010).

### *2.3 Adverse weather conditions*

Delay in construction projects can be baffling and expensive. Chen, Okudan, & Riley (2010) asserted that “some delays can result in extra buys not initially represented, for example, included material or machine or equipment”. In any case, it is conceivable to plan for unforeseen delays so they won't be hindering to the project, or its course of events but inclement weather conditions can influence a construction project course of events thereby extending the completion date beyond necessary. The more it takes to finish a project, the additional cost it attracts and incurs (Chen et al., 2010).

### *2.4 Poor managerial capabilities*

Poor management skills convey dependable impacts and may affect a whole project. The consequences of harmful, misinformed authority reach far and wide on a construction project which can result in cost and time overrun on the project beyond the initial budget (Shen, Wu, & Ng, 2001).

### *2.5 Poor motivation of the employees*

The management should be aware of workers motivation as they are the mainstays of the project. Motivation of workers have the capacity to influence their productivity on the construction site. Poor motivation of the labourers will defer the project and the completion date will be surpassed thereby prompting penalties (Polat & Duzcan, 2010).

Other factors are Poor Health and Safety conditions; Poor scope definition and control; Material wastage; lack of experience; design complexity, strict contract conditions; market instability (Nawar et al., 2018; Polat & Duzcan, 2010; Shen et al., 2001; Smith & Bohn, 1999)

### 3. Research Methodology

For this study, a quantitative research design was adopted to collect the necessary data and find answers to the research question. Creswell (2014) submitted that quantitative research design utilises an organised survey of questionnaires unlike qualitative design where semi-organized and open questionnaires are utilised. The primary source of data employed therefore is the use of a well-structured questionnaire, designed with questions to extract respondent's demographic information and the factors affecting cost contingency plans which are to be ranked using a 5-point Likert scale. The target population for this research study was construction industry professionals working for the government and private sector who are involved in cost contingency planning of construction projects such as Quantity Surveyors, Construction Managers, and Project Managers. The research scope was limited to Gauteng province in South Africa due to time and financial constraints. Purposive sampling was adopted in reaching out to the professionals and the questionnaire was therefore distributed through the use of google form. 86% questionnaire response was recorded as a total of 50 responses was received out of the expected 58. Statistical tools such as Descriptive statistics, Mean Item Score and Kruskal-Wallis H-test was used in analysing retrieved data.

### 4. Findings and Discussions

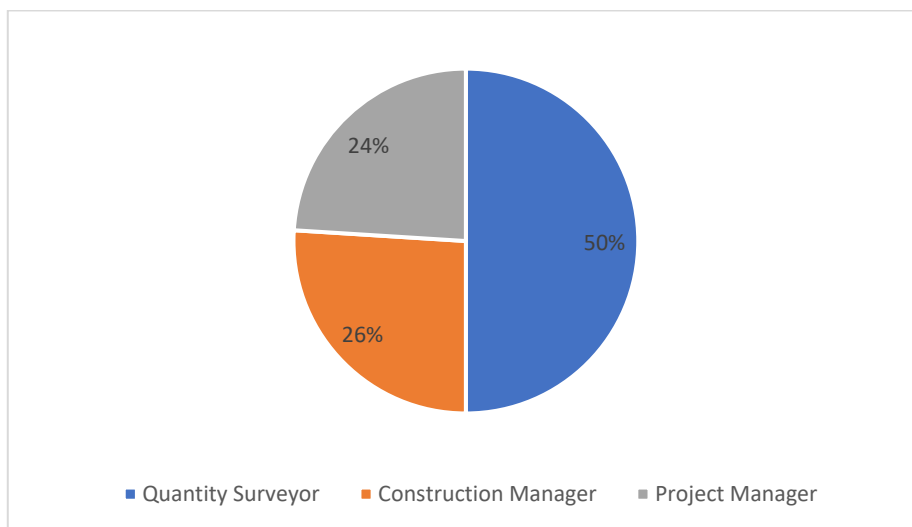


Figure 1. Respondent's Profession

From figure 1 above, the study shows that 50.0% of the respondents are Quantity Surveyors, 26.0% of the respondents are Construction Managers, 24.0% of the respondents are Project Managers.

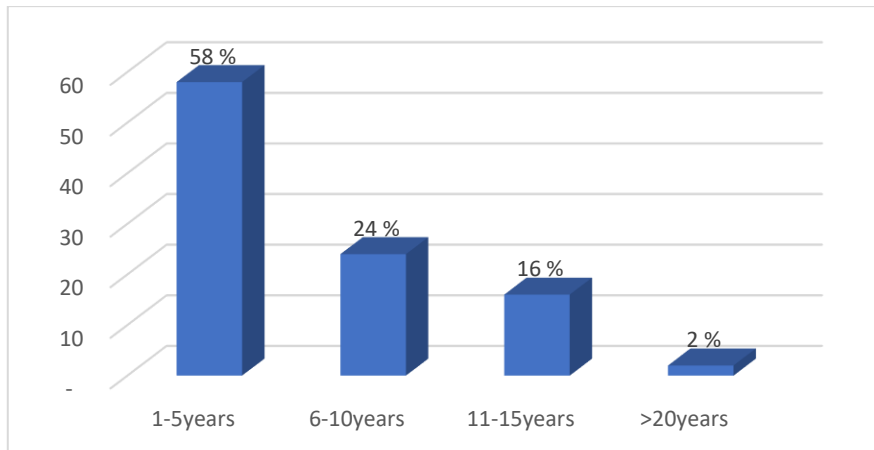


Figure 2. Years of experience of respondents

Figure 2 indicated the years of experience of the respondents with 58.0% of the respondents having between 1-5 years of experience, 24.0% have between 6-10 years of experience, 11.0% have between 11-15 years of experience, 2.0% of the respondents have experience of more than 20 years and none of the respondents had between 16-20 years working experience.

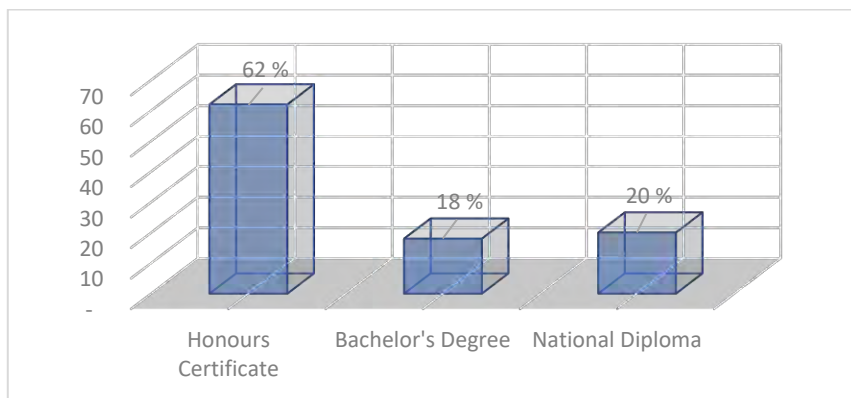


Figure 3. Highest qualification of respondents

Figure 3 above shows the respondent's highest educational qualification. It was revealed that 62.0% of the respondents had Honours certificate, 18.0% of the respondents had bachelor's degree and 20.0% had National Diploma. None of the respondents had both master's degree or doctoral degree. Based on the demographic information of the respondents, it can be concluded that they have the required experience to give reliable advice on the impediments of cost contingency plans for construction projects in the South African construction industry.

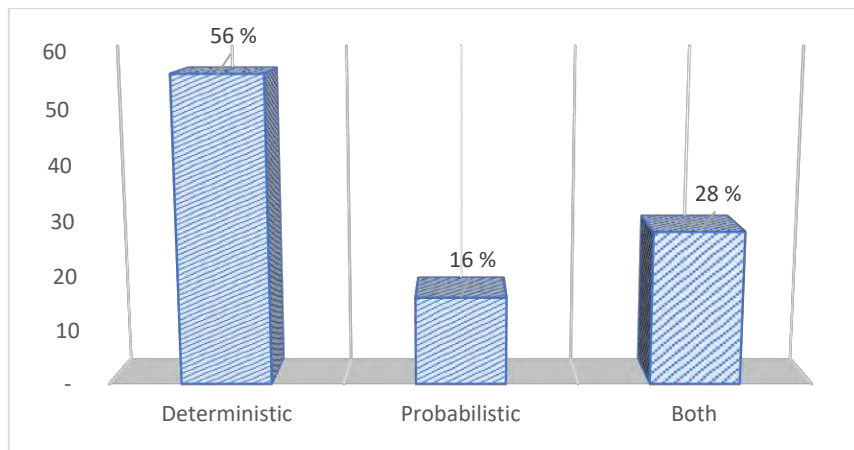


Figure 4. Methods of preparing cost contingency plan

Figure 4 shows the methods of preparing cost contingency plans frequently used in the construction industry. 56.0% of the respondents use deterministic method (cost-based estimate), 16.0% uses probabilistic method, while 28.0% used both methods in preparing cost contingency plans.

Based on the reviewed literature, various factors affecting cost contingency plans for construction projects were identified and respondents were told to rank their agreement with these factors using a 5-point Likert scale. The analysis of the responses is shown in table 1. Kruskal-Wallis H-test from the table shows that the Asymp. Sig. values are all above 0.05 except for variable ranked second (poor estimates). This, therefore, is an indication that there are no statistically significant differences in the views across the group of respondents on the variables. The lower the Kruskal-Wallis Asymp. Sig. value, the bigger the difference in the views across the group of respondents. It was also revealed from table 1 that all the variables ranked above 3.00 which is the average value for the 5-point Likert scale used. This can be interpreted thus; all the factors contribute largely to the inaccuracy of cost contingency for construction projects.

Table 1. Accuracy of Cost contingency plans

Factors Affecting the Efficacy of Cost Contingency Plans	MIS	Chi-Square Value	Asymp. Sig.	Rank
Poor planning	4.44	2.49	0.87	1
Poor estimates	4.34	10.45	0.05	2
Lack of experience	4.22	2.98	0.25	3
Poor scope definition and control	4.18	5.67	0.09	4
Design complexity	4.16	9.48	0.39	5
Adverse weather conditions	4.12	3.59	0.16	6
Material wastage	3.96	5.23	0.73	7
Poor managerial capabilities	3.96	8.31	0.16	7



Strict Contract Conditions	3.96	0.48	0.78	7
Market instability	3.76	1.62	0.03	10
Short bidding time frame	3.72	6.27	0.43	11
Schedule accuracy	3.72	6.99	0.30	11
Poor motivation of the employees	3.66	8.64	0.13	13
Differing site conditions	3.62	0.47	0.79	14
Unavailability of qualified workforce	3.58	3.23	0.99	15
Poor health and safety conditions	3.55	3.78	0.10	16

\*MIS = Mean Item Score, Asymp. Sig = Kruskal-Wallis Asymptotic Significant value

Poor planning ranked highest among the factors that affect the accuracy of cost contingency planning in the construction industry followed by poor estimates and lack of experience in second and third positions respectively. This shows that when the project planning phase is not done accurately such that poor estimates are generated based on the lack of experience of the project team, the cost contingency allowance made for the construction project will not be accurate thereby leading to overrun on the construction project. This agrees with the findings of Polat and Duzcan (2010) and Nawar et al., (2018) who found out that planning done by the project team gives proper insight into the project needs and how they are to be met. Poor definition of scope and control of scope during execution of project ranked fourth with Design complexity ranking fifth. When there is difficulty in understanding the construction project design, it creates a problem such that the scope of the project might not be adequately defined. This will eventually lead to changes in the scope during the construction phase of the project and expose the project to overrun which the approved cost contingency might not be able to cater for completely. The findings of the study are in tandem with the findings of (Buertey et al., (2012); Enshassi and Ayyash, (2014) Nawar et al., (2018); Polat and Duzcan (2010); Smith and Bohn (1999) who examined the factors affecting the accuracy of cost contingency in different countries. Enshassi and Ayyash (2014) further classified these factors into 12 categories which are owner/consultant, environmental, political, economic, related to bidding, related to construction, related to project, related to contractor, related to design, related to resources, technical/managerial, and legal factors.

## 5. Conclusion and Recommendation

This research study showed that a good contingency planning will always have clear triggers for uncertainties in which triggers can be estimations and budget assumptions that are proven to be pointers. With the triggers in place, the project team can get the accurate and fast read on changing orders by closely keeping an eye on those factors linked to the triggers. It can be concluded that proper planning and adequately prepared estimates based on sound experience of the project team will assist in making precise cost contingency planning for construction projects. This will give more credibility to the allowance made in the contract sum for contingency. This study, therefore, recommends that possible risks must be identified and evaluated before the construction project is embarked upon. This will inform the value of cost

contingency to be added to the project cost to cater for uncertainties that may occur during the construction phase. This study was limited to Gauteng province of South Africa, for a broader contribution to the body of knowledge, the study can be extended to other provinces while further study can be carried out on the excessive use of contingency on construction project for corrupt practices.

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# EPC 4.0 - The Quest of Reducing CAPEX in EPC Projects

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## Abstract:

Engineering, Procurement and Construction (EPC) Business in Europa is increasingly under pressure. Lack of productivity, low or negative profit margins for investors as well as the lack of adopting necessary innovations and digitalisation - from engineering activities through operations & maintenance to decommissioning - has caused significant deprivation of business and competitiveness compared to emerging providers in Asia. The quest of reducing CAPEX in EPC Projects is intensifying.

In May 2018, a research project was started to analyse situation and key trends through desk research, to research how the challenges of the business could be tackled and to derive practical guidance for EPC Contractors as well as for investors, owners and operators (O/O). The aim of the project was to propose innovative ways of improving the EPC Business model in order to reach the next level (“EPC 4.0”). In doing so, lessons learned from automotive and aviation industry were considered.

Key objective of the research project was to challenge statements of international EPC experts to cut capital expenditures (CAPEX) by 40% to 50% in EPC projects. With these statements in mind, the research focused on identifying measures with potential in six areas: 1.) Digitalisation, 2.) Partnering, 3.) Flat Supply-Chains, 4.) Flexible organisations, 5.) Core competences and 6.) the Human Factor. Summarizing the findings in these areas, the EPC 4.0 project came to a savings potential of up to 50% of the total budgeted project costs.

*Keywords: EPC; CAPEX; competitiveness; productivity; digitalization; partnering; human factor*

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## 1. Introduction

The financial crisis in 2008 and the oil price crash in 2014 severely hit the profitability of operations in the oil and gas, chemical, energy, and other associated industries, and consequently the engineering, procurement and construction (EPC) business that is built on the investments in these industry sectors. Low commodity prices in recent years have continued to discourage investors from financing industrial production. The industry is still suffering even after a full decade, but not only because of this crisis. Low productivity growth, low degree of digitalization, low investment in R&D has disconnected this industry from the positive evolution that other industries have experienced over the last ten to 20 years – the stock market is celebrating successes elsewhere. While the Dow Jones Industrial Average increased in the ten years from 2008 to 2018 by more than 80%, the Dow Jones Construction Index fell by 30% in the same period.

However, there is still significant demand for industrial plants. The world population is growing; production output will continue to grow on global scale, and the need to build new

production facilities will do, too. The backlog of ten lost years for EPC industry is immense. Brownfield investments to revamp existing facilities add to this huge market. The engine of EPC business has started up again. But nothing will be the same as before 2008. Because the traditional business model in EPC has no future.

Prominent voices are calling on the industry to cut its CAPEX by 40 to 50%. This doesn't just mean fine tuning of performance; this ambitious target necessitates radical changes. Within the entire value chain from CAPEX to OPEX, from the EPC of industrial plants to their operation and maintenance, money is wasted as a result of disastrous project planning and execution, and inefficient operations. Money is spent that does not add any value to basic business objectives. The CII (Construction Industry Institute, Texas) determined that 40% of project costs are just transactional costs – imagine the potential of cutting these down! A radical business transformation that would put the EPC business on par with the efficiency of the automotive or aviation industry would unleash money from investors. There is no lack of money. The EPC sector is simply not effective enough to attract it!

In May 2018, a German think-tank kicked off an innovation initiative to develop practical guidance for EPC contractors as well as for investors, owners and operators on how to approach innovative business models for industrial projects and operations, from EPC to O&M. The research focused on qualitative methodology rather than on quantitative figures to capture the nuances of practice and provide insights from practitioners for practitioners. Wherever quantitative figures are referred to, they are intended to provide an indication of the 'hidden potential' and should not be misunderstood as statistic values.

Based on practical experience, an in-depth analysis of the present situation, key trends for the business and the need for change was done, scanning a multitude of reports, articles, conference proceedings, and literature. Ideas how business could improve were developed and validated during in-depth interviews with twenty industry representatives. During conferences and intensive workshops potential solutions were discussed and refined, before an online survey captured the magnitude of cost reductions in each area. Case studies were identified for each improvement area, highlighting the realization of improvements in practice and discussing advantages together with disadvantages.

This article summarizes the actual situation and key trends, highlights the potentials for improving the EPC Business with targets for CAPEX savings and concludes on the results.

## **2. Situation of the EPC Business**

The term “EPC” refers to a particular form of contracting arrangement used in some industries where an EPC Contractor is made accountable for a multitude of activities - from design, procurement, construction, to commissioning and handover of the deliverables to the owner or operator. EPC projects are typically large and complex. They can be found in many industry segments, including but not limited to industrial plants, oil and gas, mining, power generation or large infrastructure (Wagner, 2018).

15. September 2008 is a historical milestone that marks a turning point for the EPC industry. The day Lehman Brothers collapsed and stock exchanges around the world lost billions

of Dollars was the starting point for one lost decade in EPC business. The price of crude oil is the most prominent indicator determining overall economy performance. The World Bank publishes its outlook (Worldbank, 2018) of commodity prices quarterly, and owners/operators of industrial plants producing commodities carefully plan their investments in step with this prognosis.

The oil price had climbed to an unprecedented spike in 2008, driven by the rapidly increasing demand in the emerging economies, but also production cuts by the Organization of the Petroleum Exporting Countries (OPEC), before it collapsed as a consequence of the global recession triggered by the financial crisis in 2008.

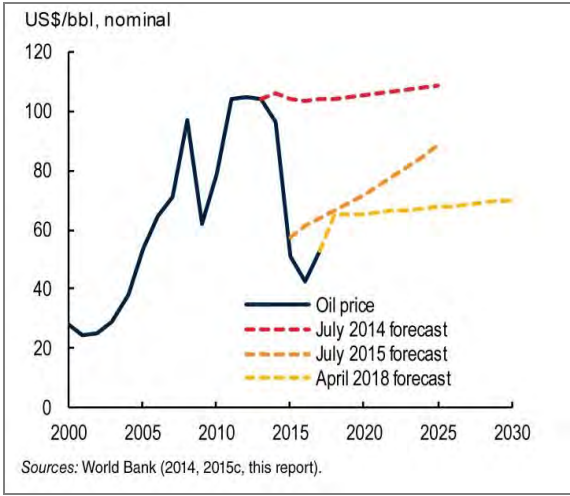


Figure 1: Commodity Markets Outlook, April 2018 (Worldbank, 2018)

Economic recovery sent back the oil prices to levels above 100 to 125 USD between 2010 and 2014, before it suffered another steep drop in 2014. This second drop was caused by the same economies that fuelled the oil price with their massive demand the years before, and then struggled to maintain their growth, above all China, followed by India, Russia and Brazil. The high oil prices in 2010 to 2014 triggered North America to expand its own capabilities to extract the black gold from their oil sands, further contributing to the negative effect of low demand. Last but not least Saudi Arabia continued to exploit its resources with high production levels. All in all, the oil price collapsed to levels down to 40 USD and has not recovered since. The World Bank forecast has been corrected to lower levels in recent years, and the pressure remains on all investors to plan their business based on continuously low commodity prices, putting high pressure on CAPEX as well as OPEX.

As a consequence of the collapse not only of the oil price, but also of the price of other commodities such as natural gas, owners put their investments on hold. The result was a dramatic decline in order intake for those companies that were relying on orders from industrial plant operators, EPC Contractors, the supply chain of manufacturers, but also service providers in all fields, including operation and maintenance.

The strong decline in order intake hit developed economies such as Germany especially hard. The VDMA (Germany’s Mechanical Engineering Industry Association) determined that the order intake for the large EPC projects by German companies dropped from 33 billion Euros in 2008 down to 19 billion Euros in 2016 (VDMA, 2017). Companies with low capital assets collapsed, others were forced to merge, and yet others were subject to acquisition by healthier competition, often based in Asia.



Figure 2: Order intake for large EPC Projects in Germany 2008-2016 (VDMA, 2017)

The rise of China is another game-changing factor for the global economy, and specifically in the EPC Business. While western economies are lacking long-term strategies, western governments acting from one election to the next, and western companies acting from one quarterly report to the next, China’s strength is long-term planning. China is investing where the Return-On-Investment (ROI) may pay back not before five, ten or even twenty years, while western companies are struggling with the massive decline in their business and consequently cannot release the cash to invest.

Global competition has always been strong, and companies have their strategies to face this competition. Competition from China, however, is felt as the toughest-ever threat to European companies. There is only one way out: European companies have to remember their strengths and have to invest in the fields of their strengths and have to defend – or regain – their leading position. Without investment into long-term strategies this contest will be lost by European companies. The good news is: After a lost decade for the EPC Business, after a decade of low demand for industrial production facilities, this market is starting up again. The backlog of one decade is immense, and the growing world population will guarantee a continuous demand for new capital projects. The market is big enough for it to require all available engineering resources in this world.

There is no precise definition of “EPC Industry”, consequently there are no reliable reports that determine the size of the global EPC Market. Many reports refer to the global construction market, which is estimated to be a 10-trillion-USD market today and is expected to grow to 15

trillion USD by 2030 [Global Construction, 2015]. Growth is driven primarily by the economies in China, India, the US and South-East-Asian economies such as Indonesia, while the traditional players Europe or Japan may recover but will not surpass the levels prior to the financial crisis in 2008. Construction industry includes real estate and infrastructure, which make up the largest part of the market, but it can be assumed – depending on the definition of EPC Industry – that EPC Business has a share of 6 to 10% of this market.

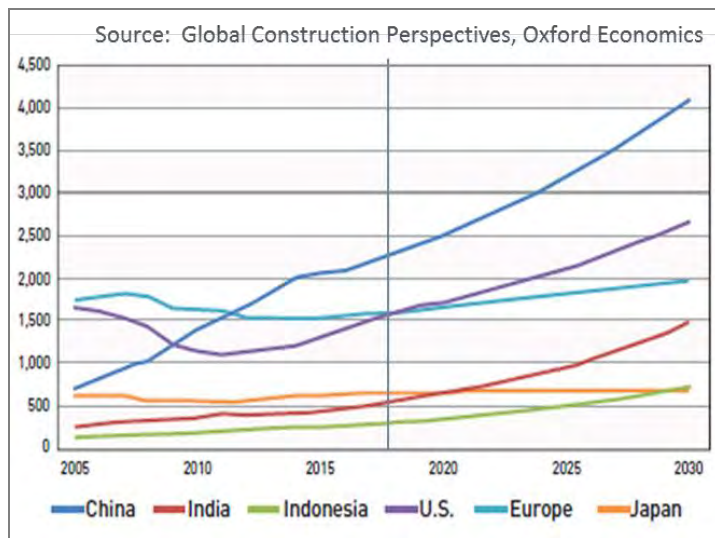


Figure 3: Forecast of the Global Construction Market 2030 (Global Construction, 2015)

A global market size for EPC projects of 600 to 1000 billion USD per year, and a market growth of 50% over the next 15 years requires all players in this market to organize themselves more effectively to be in position to execute all these projects. Considering that we are currently executing projects with an average cost overspend of more than 30%, there are huge opportunities in this market that would justify massive investments into the companies that execute these projects. However, as long as there is a poor performance of the EPC Industry compared to other industries, investors are reluctant to invest in this business.

Investors are driven by the leading financial indicators. The Dow Jones Industrial Average (DJIA) dropped dramatically with the financial crisis in 2008, however, it managed to recover to previous heights within five years. Within one decade (01/2008 to 01/2018), the DJIA increased by 86% -attractive for those who invested their money in this market. The Dow Jones US Heavy Construction Index (DJCI) is a leading indicator for the construction industry in general, and (to a certain extent) can be taken as an indicator for the EPC Industry. The DJCI suffered a dramatic drop in 2008 as well, but even after five years it still remained 30% below its pre-crisis level. Another five years later, its performance had still not improved. While investors celebrated the record heights of the DJIA, those investing in the market represented by the DJCI suffered 30% losses after one lost decade.

There are several reasons for the massive underperformance of this sector, and there is a wealth of studies and reports by all major business consultants that come to very similar results. From all these studies, three major factors are highlighted here:



- *Poor performance in the execution of capital projects*

Studies, for example by McKinsey (McKinsey, 2017a), conclude that capital projects are completed with an average of 37% cost overspend and 53% schedule overrun. The magnitude varies from sector to sector, but the oil & gas downstream business seems to hold the record with an average of 53% cost overspend.

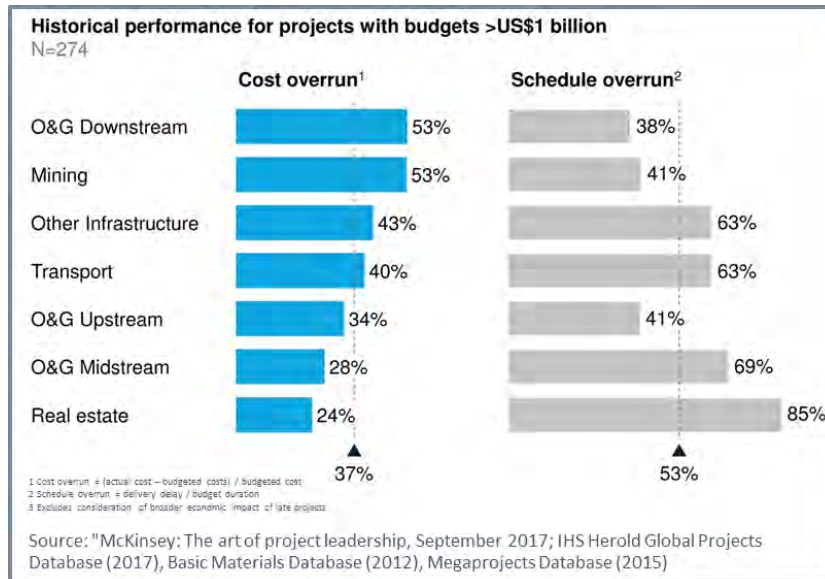


Figure 4: Performance of megaprojects (McKinsey, 2017a)

The reasons for these massive losses have been analysed and the conclusions are the following (McKinsey, 2017a): “The failures in the core processes of project under-performance are well understood: post project reviews generally audit the systems, process, and project management root causes for overruns. However, the disruptive influence of failures in project leadership, ineffective culture of the project organisation, failed mechanisms of collaboration between multiple parties involved - and their increasing importance as the scale and complexity of projects increase - are typically not examined to the same extent.”

The report for the World Economic Forum in May 2016 prepared in collaboration with Boston Consulting Group (BCG, 2016), refers to these reasons for failure:

- Lack of innovation and delayed adoption
- Informal processes or insufficient rigor and consistency in process execution
- Insufficient knowledge transfer from project to project
- Weak project monitoring
- Little cross-functional cooperation
- Little collaboration with suppliers
- Conservative company culture
- Shortage of young talent and people development

- *Poor productivity growth compared to other sectors*

Productivity has grown continuously over the last few decades, between 50 to 70% for the overall economy within the past twenty years. Manufacturing has been leading productivity growth, almost doubling its real gross added value per hour worked by person employed between 1995 and 2015 (McKinsey, 2017a). Productivity in construction registered minor growth during the same period.

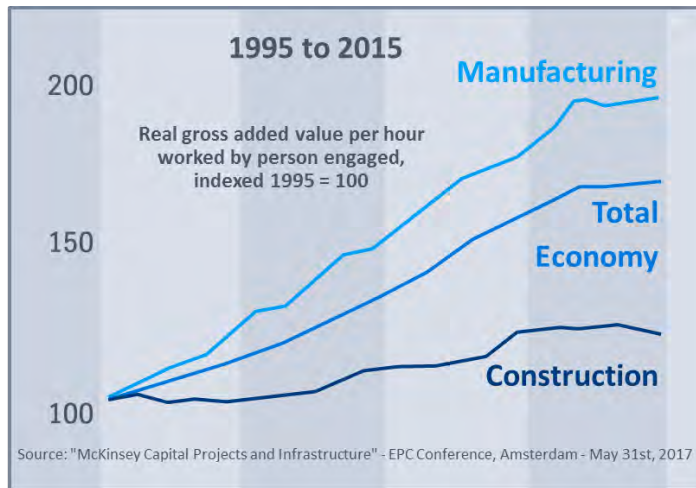


Figure 5: Productivity in Construction (McKinsey, 2017a)

- *Low level of digitalization*

Another explanation for the massive productivity gap of our business in comparison to other industrial sectors is the low level of digitalization. Again, we can refer to several analyses performed by major business consultancies, in this case the TOP 500 Study 2014 by Accenture (Accenture, 2014).

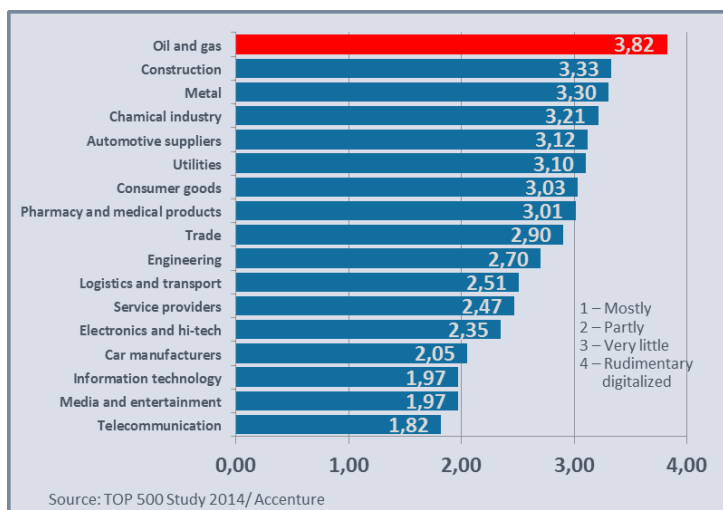


Figure 6: Digitalization by Industry Sectors (Accenture, 2014)

While the elimination of the deficiencies that lead to massive under-performances in the execution of projects is an obvious measure to be taken by all companies in this sector, the players shall focus on the opportunities expected from closing the gap in the industry ranking (first) in digitalization, resulting (second) in the productivity growth that this industry needs to compete successfully for the investors' money in the global market.

### **3. Key trends for the EPC Business**

The starting point of this 'EPC 4.0' initiative was a white paper 'Time for Change – A vision for EPC 4.0' issued by ProjectTeam in November 2017 [ProjectTeam, 2017]. From the variety of studies and reports that analyse the situation in the EPC sector, and from the variety of issues that are addressed by speakers at conferences held over the globe, we have identified some megatrends that we have used as the initial project charter for our own analysis:

- *Collaboration between O/O and EPC Contractor*

The traditional approach in EPC business to execute a project based on a lump-sum turn-key (LSTK) contract between the owner/operator and EPC Contractor is adverse to the idea of joint collaboration. The LSTK contract causes each contractual party to focus on its claims against the other party and adds additional contingencies to budgets and schedules to protect against claims and to deal with uncertainties.

There is a trend for investors to think about strategies on how to marry CAPEX and OPEX and form one integrated project team with the key players for the execution of the CAPEX project. Project Alliance Contracts are one model in which each party is incentivized to optimize both the CAPEX and the OPEX of the plant. Uncertainties and the consequential contingency costs are reduced owing to open books. Sustainable long-term-goals should prevail before short-term deadlines.

- *Collaboration with the Supply Chain*

The traditional approach contracting the work from top (O/O) to bottom through several levels to the EPC contractor, subcontractors and their sub-suppliers in a contractual hierarchy generates losses of 40% of project costs as transactional costs. Relational contracting rather than roll-up contracts will flatten the supply chain, replacing the contracting hierarchy with a network.

Modularization and standardization are good measures to improve the integration of the supply chain into the plant design, but standardization to cut CAPEX should not compromise any optimization of OPEX. Many components, however, are over-specified, and costs can be saved by eliminating these over-specifications. Scalable and agile platform strategies such as in automotive design permit standardization without eliminating necessary variances.

The traditional approach is to buy and own the equipment. A different approach is to lease equipment over a period of time, which levels CAPEX costs. Alternatively, equipment may be paid-per-use, with the equipment supplier remaining the owner and maintaining the equipment over the life-time. This option could be attractive for suppliers of complex machinery, not only

because of the profit generated in service contracts, but also because of the opportunity to feed experience from operation and maintenance back into design improvements.

- *Flexible resourcing and agile EPC Collaboration*

Labour markets in high-cost countries do not provide sufficient qualified resources, with the consequence of further increasing labour costs. Companies with global hubs are shifting qualified work to low-cost countries. Fluctuations of staff (e.g. job-hopping), as experienced in Asia, will become common in high-cost countries, too. Highly qualified staff is not willing to accept cuts but moves on to where the work seems more attractive.

Companies are taking the approach of replacing hierarchies with network organizations that develop the flexibility to upscale and downscale their capacities to accommodate the huge upturn and downturn cycles in EPC Business.

- *Digitalization and Industry 4.0/data and knowledge sharing*

Potential new players might position themselves as providers of EPCaaS (EPC as a Service) and/ or Project Management Consultancy (PMC). They would offer a software-based solution and apply Building Information Modelling (BIM) to manage the development and construction of a capital project.

The opportunities of digitalization and industry 4.0 will require the EPC Contractor and the owner/ operator to build a partnership over the asset life cycle. The real value can be generated when the technology provider shares his engineering data with the operator, and the operator shares his O&M data with the technology provider. The analysis of big data from multiple plants leads to plant and process improvements that both technology provider and operator benefit from.

- *Project Management and Competencies*

Projects fail because the established and known project management methods and tools are not applied. This is not about innovation; this is about bridging the gap between theory and reality, between knowing what's wrong and doing what's right. The problem is not that processes or tools must be invented; the problem is the change of mindset in the organizations and their people, and how to manage a culture of change.

Agile project management methods are successfully applied in other industries, especially in innovation-driven businesses, such as software development. There may be a conflict between the necessity to digitalize the project management processes with controlled data workflows that may lack flexibility and the trend to agile project management methods. This conflict needs to be addressed and resolved.

#### **4. Hidden potential of the EPC Business**

Today, industries are under permanent pressure to change and adapt. Innovative technologies, products and services brought to market by companies in global competition create a race for leadership in all sectors of the economy. European companies in the EPC Business cannot escape this pressure and aspire to catch up in this global race. However, much remains to be done, as the EPC Business in Europe has fallen far behind in recent years and must now make even greater efforts.

In recent years, studies have repeatedly revealed the gaps in European EPC Business in terms of innovation, productivity, profitability and business agility. European companies in the automotive, aerospace, mechanical and electrical engineering as well as automation industries have worked continuously to improve their performance in recent years and are now among the global champions. It is essential for the European EPC Business to catch up and improve performance significantly. This is not a question of a marginal improvement, but a quantum leap.

Prominent voices in the European EPC Business are calling for significant changes, for example the Global EPC Manager of Shell, Paul van Weert, who advocated during the ECI Annual Conference '18 (ECI, 2018) in Amsterdam: “We need to halve the cost of capital projects to enable them to do twice as many projects with the same allocated budget, not through putting more cost pressure on supply chains, but through fundamentally rethinking the delivery model.”

In summary, a step change in the way projects are executed is needed to secure improvement of up to 50% in cost as well as 30% in schedule. That won't be achieved by squeezing the margins of suppliers, but calls for much deeper collaboration, more rigour in scoping projects, relying more on what the industry has on offer, standardization, less prescriptive standards from the client and using digital twins more effectively from design through construction to the operation phase.

Stephen Mulva, Director of the Construction Industry Institute (CII), paints a dramatic picture of the situation and argues that the transactional costs are too high (CII, 2018): “For the past several decades, our industry has emphasized the planning, technical, managerial, and work process dimensions of our projects – at the expense of the numbers and the assets keeping us in business. Forty percent (40%) of the cost of creating a new asset is currently wasted on transactional costs. It's not a sustainable model. We have to employ the best business, financial, and accounting concepts and we've got to do it now.”

Transactional costs may be defined as costs associated with the exchange of goods or services, including payments to banks and brokers, search fees as well as service fees to process these transactions. In EPC Business, transactional costs may also include financial fees, legal fees, dispute resolution costs along with logistics and communications costs. It also includes foundational work such as the cost of sourcing quotes, cost and schedule benchmarking, assurance reviews and so on and so forth. Unfortunately, in EPC Projects, transactional costs thrive owing to both lack of integration, and to contractual and operational frictions between the multitude of stakeholders involved during the project lifecycle.

Mulva advocates a new approach, the “Operation System 2.0” [CURT, 2018]. This vision is a multi-industry, collaborative, research-supported effort that aims to reorganize industry procedures and standards and replace them with a standardized, technology-enabled platform that accommodates future changes and makes capital projects more financially viable and sustainable.

In an interview with digital AGENDA (dA, 2018), he points out the impact: “The existing business model is essentially like a pyramid: At the top you have the owner, followed by the EPC, a series of subcontractors, a series of suppliers, and they are working on the contract, both upwards and downwards. This model is very slow and expensive. With computers and AI, we are able to put basically everybody on what we call the Thin Platform OS 2.0. Impact can reach up to 35% cost reduction, 50% cycle time reduction, 57% better ROCE and 250% more projects.”

In 2017, an in-depth report of McKinsey experts examined the role of technology in shaping modern industries (McKinsey, 2017b). The authors conclude that digitization is driving a “radical reordering of traditional industry boundaries,” leaving whole sectors ripe for disruption. “The mobile Internet, the data-crunching power of advanced analytics, and the maturation of artificial intelligence (AI) have led consumers to expect fully personalized solutions, delivered in milliseconds. Ecosystem orchestrators use data to connect the dots - by, for example, linking all possible producers with all possible customers, and, increasingly, by predicting the needs of customers before they are articulated. The more a company knows about its customers, the better able it is to offer a truly integrated, end-to-end digital experience and the more services in its ecosystem it can connect to those customers, learning ever more in the process.”

In another McKinsey report concerning “The art of project leadership: Delivering the world’s largest projects” (McKinsey, 2017a) it is stated that “troublingly, large capital projects that are completed on schedule and within budget are the exception, not the rule. We reviewed a dataset of more than 500 global projects above US \$1 billion in resource industries and infrastructure and found that only 5 percent of projects were completed within their original budget and schedule. In completed projects, the average cost overrun was 37 percent and average schedule overrun was 53 percent.” It is pointed out that the disruptive influence of failures in project leadership, ineffective culture of the project organization, failed mechanisms of collaboration between multiple parties involved are some of the levers for improving the performance of large projects, especially as scale and complexity of projects are increasing.

Last but not least, it is essential that the productivity gap in the EPC business is dealt with. Reports (McKinsey, 2017c) point to the fact that in the construction industry the annual productivity growth during the last two decades has been only 1%, that the industry is lagging behind overall economy productivity by 50% and that in total a boost in productivity of approximately 50-60% could be achieved, which amounts to \$ 1.6 trillion additional value:

“Construction is among the most fragmented industries in the world, the contracting structures governing projects are rife with mismatched risk allocation, and owners and buyers, who are often inexperienced, must navigate a challenging and opaque marketplace. The results

are operational failures within firms, including inefficient design with limited standardization; insufficient time spent on planning and implementing the latest thinking on project management and execution; and a low-skilled workforce. In addition, the construction industry is highly volatile and has bottom-quartile profit margins compared with other sectors, constraining investment in the technology and digitization that would help raise productivity.“

Summing all the findings up, there is a real potential for the EPC business to improve its overall performance. All reports show measures for drastically reducing costs as well as scheduled times, for improving the overall productivity by learning from good practices and other industries, performing systematic organizational change and by using modern technologies to the best extent.

## **5. Results and conclusions**

After studying a multitude of reports, discussing the matters with about a hundred experts and analysing more than a dozen case studies we are able to conclude that it's possible to save more up to 50 % of CAPEX in EPC projects! However, unleashing the potential depends on a number of factors that need to come together.

First of all, the EPC Business is complex, and every business, every project is special. There is no standard solution that fits all. Solutions that may work in one business case might fail in the other, as ownership structures, regional aspects, technical conditions or the markets are completely different. This is why our research had to consider a multitude of perspectives.

Second, no individual player within the value chain will accomplish this target on their own. CAPEX is the total of capital expenditures, including the costs of project development, the costs of engineering/procurement/construction, the cost of project management and project governance. Such a radical reduction may only be feasible if developed along the entire value chain, and here the first link in the chain is the investor. The investor defines the strategy for project development, and decides between the traditional 'LSTK' approach or an innovative partnership approach that takes on board the experience and competence of all parties involved from the very first moment. The next in the chain, the EPC Contractor, is also not able to realize 50% cost savings if sub-suppliers do not contribute to this, and if all sub-suppliers had not passed these savings on to their respective customers in form of reduced prices on their scope of supply and services. Finally, one of the levers is to reduce supplier tiers from five or more to three or less by applying cooperation agreements.

There are success factors and reasons for failure that follow a larger pattern, and the goal of our research was to capture and evaluate these factors, and to give structure to the overall pattern in a holistic approach. The model we used is a holistic model for business transformation covering four success-critical dimensions, 'People', 'Organization', 'Processes & Methods', and 'Technology'.

The basic principle of this model is the experience that any business transformation needs to happen balanced across all four dimensions. Initiatives that limit the effort to cover one or two of these dimensions will fail if the other dimensions are neglected. Therefore, recommendations are assembled in the format symbolized by a 'temple', with digitalization as

the leading (and potentially disruptive) technology foundation. On this foundation we define four pillars of organizational and process/methods-related changes, covered by the roof of human behavioural changes – the people dimension and ultimately the most challenging part of all.

**Digitalization** is the foundation. Ten years ago, most experts would have agreed to the thesis that we should first define the processes, and then select and define the corresponding IT solutions. In the age of Industry 4.0, we recognize that IT is developing new solutions and new opportunities at a speed that our business processes are hardly capable of following. We are too slow in evolving our business processes to give them the lead; digitalization is the driver that imposes changes, sometimes disruption on traditional business models. In other industries this is already reality, and we should not exclude the same happening in future in the EPC of industrial plants. The title of the initiative “EPC 4.0” references Industry 4.0 as a ‘fourth’ industrial revolution driven by (software) releases.

We have identified four major fields of action to address changes in organization and in processes and methods, which are all linked to each other:

**Collaboration by Partnership** makes reference to the public infrastructure sector, suggesting specifically that investors/owners/operators consider contractual models different to the traditional EPC LSTK approach, such as alliance contracts or Lean Integrated Project Delivery (IPD) models (AIA, 2007).

**Flat supply chain** references examples of supply chain integration from the aviation and automotive industry, suggesting partnerships with strategic suppliers that go beyond the capital project horizon and into the field of operation and maintenance.

**Flexible organization** advocates standardization of project management, engineering, procurement and construction processes as well as standardization in qualifications to enable the EPC Business to adjust flexibly to business cycles with organization structures scalable to market needs.

**Focus on core competences** finally suggests that all participants share work scope and associated risks with the party who is best capable and competent of managing these. This focus releases resources for urgently required innovations: Innovations in plant technology, such as modularization, innovation in state-of-the-art information technology to increase productivity and reduce non-conformance and underperformance costs.

**The Human Factor.** All these changes will not be successful without the support of the people working in our industry. The magnitude of changes triggered by Industry 4.0, in organizations, in processes and methods, requires a transformation programme driving a cultural change in the behaviour of our human resources. There are well-established tools and methods to guide organizations, companies, or project teams to work towards a change in attitude and mindset.

A reduction of up to 50 % of CAPEX? What at first glance may look like utopia may not be impossible if broken down into smaller elements where we are wasting money in our capital



projects today. Planned CAPEX and the as-built CAPEX in reality differ significantly — the cost overspend in megaprojects ranges between 30 to 50 % on average!

But even when we analyse the planned CAPEX: The cost of lost productivity, transaction costs that do not add value, such as the costs of mark-up fees, the cost of duplicating project organizations for project governance, the cost of bidding, the cost of claiming and penalties, the cost of risk contingencies in CAPEX... All in all, we come to the conclusion that up to 50% of the money we spend on capital projects is avoidable and does not contribute to the value of the assets we build.

The following example is not aimed at proving the feasibility of saving up to 50% CAPEX. The savings potential is limited by the nature of the business case, market conditions, owner's structure, region of project execution and operation and many other factors that impact the cost breakdown of CAPEX. However, it invites investors, owners and contractors to explore the savings potential for their specific business cases if the measures described in this report are implemented successfully.

With the random example a CAPEX cost breakdown is provided, with a 13% share of the owner's costs, and a 87% share of what in a LSTK set-up would be the EPC contractor's share. We are aware that some projects come with owner's costs as low as 10%, while in others the owner's costs make up a share up to 30%. Costs of engineering can vary in a range from as low as 5% to as high as 30%, depending on the degree of engineering re-use and depending on the location of the engineering team in a high- or low-salary region. The share of construction costs, specifically construction labour, may be significantly higher if the project is executed in a high-cost region, e.g. the US or Northern Europe. The share of equipment and (bulk) material costs depends on the technology of the plant. Consequently, the figures below are not representative for "EPC projects" in general, as they can illustrate one dedicated example only.

In the calculation presented below, the cost breakdown can be read as absolute figures, representing a project with a total budget of 100 Mio EUR, or as a percentage. The individual savings are multiplied to determine the total saving, and it is important to understand that the levers in each saving category must be different and independent from each other. In this example we have identified four major (and independent) levers to achieve savings: Team integration, productivity, transaction costs and schedule acceleration.

Cost Element	Cost Breakdown before savings	Team integration	Productivity	Transaction costs	Schedule accel.	Total Savings	Cost Breakdown after savings
Owner	13	50%	30%		20%	<b>72%</b>	<b>4</b>
Project Management	6	50%	30%		20%	<b>72%</b>	<b>2</b>
Construction & Start-Up Management	8	50%	30%	10%	20%	<b>73%</b>	<b>2</b>
Engineering	14		30%		20%	<b>44%</b>	<b>8</b>
Equipment	21		30%	10%		<b>37%</b>	<b>13</b>
Bulk Materials	11			10%		<b>10%</b>	<b>10</b>
Construction Labor	12		30%	10%	20%	<b>50%</b>	<b>6</b>
Other Construction Costs (e.g. site logist.)	2			10%	20%	<b>28%</b>	<b>1</b>
Contingency	6			50%		<b>50%</b>	<b>3</b>
Special Costs (Legal, Travel etc)	7			80%		<b>80%</b>	<b>1</b>
	100						<b>50</b>

Table 1: Example of the cost breakdown for an EPC Project with potential savings

Team integration: The total number of personnel involved in the management, supervision and governance of the project, traditionally (more than) duplicated in parallel project organizations for the owner, for the EPC contractor, for the construction company and lower tier subcontractors may be halved just by forming integrated teams based on contractual schemes supporting partnership.

Productivity: Exploiting the full potential of digitalization, such as BIM or automation in construction management, the reduction of claims and claims defense, the integration of suppliers and the early involvement of all parties may lead to a significant increase of the productivity of owner's management, project management and construction and start-up management up to 30%. Possible productivity gains in engineering, in the manufacture of equipment and in construction (labour productivity) in the range of up to 30% may be achieved through reduction of waiting times, reduction of changes and higher professionalism in coordination and supervision. These savings are still conservative compared to the overall productivity gap between construction industry and other sectors of 30 to 80%.

Transaction costs: Reducing transaction costs (that according to CII may sum up to 40% of the project costs) is a significant lever. We point to the fact that duplication of project organizations for governance or reduction of claims are also transactional costs, but not considered here. In the example an additional reduction of up to 10% may be achieved by flattening the contracting pyramid, eliminating double mark-ups in equipment supply and in construction (management, labour, bulk material and site logistics). Another major factor is the reduction of (double) risk contingencies by a half across all levels of tier organizations from a total of up to 7 to 8% down to a range of 3 to 4%.

Finally, the category ‘special costs’ includes positions such as travelling, but to a significant share also legal costs (in some projects up to 10%!) or other costs that are associated with defending contractual positions which do not add value to the overall project. Applying the partnership approach in contracting may eliminate up to 80% of these special costs.

Schedule acceleration: McKinsey [McKinsey, 2017-1] determined an average of 53% schedule overrun on megaprojects, and the executing contractors consider this experience to certain degree in their project schedules. While this research highlights the potential saving in terms of cost (CAPEX) the same levers (such as digitalization, collaboration, productivity gains etc.) will also translate into shorter project execution times. A reduction of 20% in overall project duration and in construction duration, as considered in the example, will directly reduce the time-dependent cost positions, for example owner, project management, engineering and construction costs (management, labour, site logistics).

The example shall illustrate the potential impact of the different levers identified and described in this research to a sample cost breakdown. In this specific example, if we consider a CAPEX of 100 Mio EUR before savings, the aggregation of all potential savings will drive CAPEX down to 50 Mio EUR after savings, a reduction by 50%!

Overall the saving potential in CAPEX may be in a range of 30 to 50% of the planned costs, and this potential does not include the elimination of non-conformance costs, as these costs never enter a budget, but only will result in cost overspend. Just to recall: McKinsey [McKinsey, 2017-1] determined an average of 37% cost overrun on megaprojects.

Finally, it must be mentioned that the recommendations given in this research, such as supplier integration, operations readiness or predictive maintenance, shall also help to drive OPEX down. Finally, the improvements in CAPEX and OPEX will result in a significant better financial model for the business case, leading to better financing conditions, higher margins and finally an attractiveness for investors that can compete with other industries.

Now it’s up to the decision makers of the EPC Industry to simply start changing the business. The ones who succeed will be the leaders of tomorrow in EPC Business. A faster way of improving the business is to analyse what other industries, sectors and firms are doing and to apply lessons learned. There is no “silver bullet” to tackle the situation in EPC Business. However, it’s insightful to see how EPC is applied in other sectors and how industries such as Automotive and Aerospace are improving productivity, applying new (digital) technologies and performing agile and collaborative practices.

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# Determining Measures to Increase the Productivity of Contractors in Construction Projects

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## Abstract:

Long-standing problems with the productivity of the construction industry around the world require organizational changes in construction companies. The human work still has a dominant share in the cost of realization, therefore the increase in labor productivity is of essential importance. Possible measures are classified according to a number of criteria - towards whoever should take them, according to what they relate to, by the extent, by the time, by their action and with other characteristics.

This paper analyzes barriers to increase construction productivity and shows the algorithm for finding appropriate corrective measures. The methodology for improving the productivity of contractors is primarily focused on increasing labour productivity and is cyclically implemented. It is always necessary to measure the realized size of productivity, comparison with the reference size and the examination of a number of factors affecting it. After analyzing influential factors, appropriate measures can be taken, which is specific to each company and project.

In addition, the article provides an overview of the factors that have the greatest impact on the labour productivity in construction industry according to the results of the previous research and the list of measures that are in line with these proposed. There is in conclusion, a critical review of the situation and possibilities of such measures including contractors in Croatia. It emphasizes the need for state and clients contributed to the contractor's productivity from which everyone benefits.

*Keywords: factors affecting productivity; delays; measuring; improvement measures*

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## 1. Introduction

Productivity is an efficient transformation of resources into market products, so its improvement is primarily for any profit-oriented organization. The productivity of contractors can significantly affect timeframe and realization costs and it is important for clients, indirectly for a variety of other industries and for the economy of the whole state.

Despite technological advances, the labor force is the dominant production resource for construction work and therefore the productivity of contractors is mostly dependent on the performance of workers (Ghate and Minde, 2016), ie labor productivity.

The problem of low productivity in construction (with regard to other industries and long-lasting weak growth) is also in the most developed countries and numerous experts have tried to find practical solutions for its improvement. A lot of articles in the journals, conference

proceedings and a series of master theses and doctoral dissertations have been published, but there is no simple or universal answer to who, what to do and how to do it. But it is clear that access to productivity improvement for contractors and the realization of certain projects must be an individual, flexible and holistic, based on realization data.

## **2. Methodology for improving the productivity of construction contractors**

After seeing the need to improve the business/performance of contractors and the idea of achieving this by increasing productivity, the initial step is to get acquainted with productivity issues (background). It is also necessary to define an appropriate subsystem for monitoring productivity in the company. It can be a problem that employees dealing with data collection have other duties that are usually more important (Poirier *et al.*, 2015). Therefore, it is recommended to introduce the function responsible for improving productivity in the company (construction productivity improvement officer) (Shinde and Hedao, 2017).

Continuous monitoring of the productivity of certain types of work and the parameters of the overall project realization (Performance ratio, Project management index, etc.) is important to timely insight into losses and determine the need and possibilities of its improvement. Adrian (2008) recommends job site record keeping and defect analysis and Horner and Duff (2001), as well as Shehata and El-Gohary (2011), warn that a very important choice of a suitable method of productivity measurement. (There may be different techniques such as Activity sampling, Field surveys, Wireless Real-time Productivity Measurement, Time study, Group timing, etc.)

Productivity management is based on the collection, availability, and use of information during building (de Araujo *et al.*, 2013). It is sometimes possible to apply productivity improvement measures to the realization of a current project, and will sometimes use the acquired knowledge to plan and manage the realization of future projects (for example a risk checklist, a model for productivity estimation, internal time norms). That is why it is important to create a database that provides baseline productivity data and predicting the impact on productivity. Also, in some cases, regular records can provide a basis for possibly seeking compensation for losses from those responsible for adverse impacts (Vidaković *et al.*, 2018).

The decision to take measures to increase productivity is based on a comparison of specific reference productivity (according to time norms, baseline productivity or selected competition/good practice examples). In that, the conditions which in this case affect the performance must be taken into account. If the productivity level is unsatisfactory, the optimal way to improve it should be chosen. The basis for making decisions about this is when measuring the observed delays and detected factors that affect productivity. It is necessary to clearly identify and analyze the causes of loss of work time/productivity and which really limits the productivity increase. When deciding on appropriate measures to eliminate or reduce negative impacts on productivity, it should be kept in mind:

- the significance of the detected effects on productivity (certain weight and frequency of influence),
- linkage to the effect of some influential factors,
- costs for implementing certain measures,
- the time to take measures,

- the time when measures can begin to contribute to increased productivity,
- savings that bring the planned increase in productivity,
- the duration of the positive effect of the measures on productivity,
- a common effect of the measures planned,
- the required resources and their availability in the company.

It makes no sense to choose measures for which there are no financial resources or adequate staff. Measures should be realistically applicable and cost-effective with the realistic expectation of their performance, ie increasing productivity (eg. it is not profitable to invest in the procurement of some equipment if there is not enough contracted work to which its productivity will be paid). The described methodology for finding optimal measures for improving productivity is shown in Figure 1.

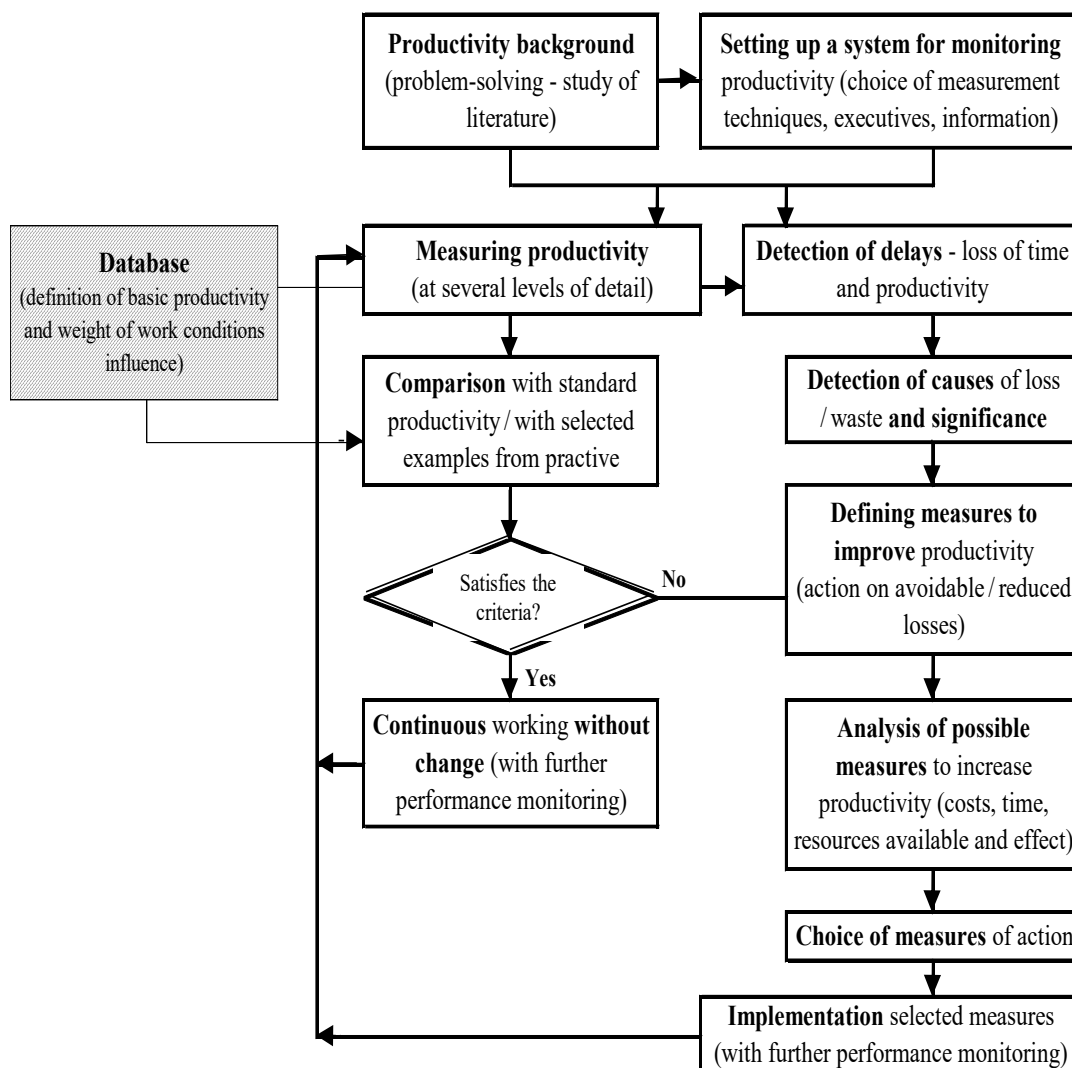


Figure 1. The methodology of cyclic improvement of productivity

It is important that at all levels of management of the contractor company there is a commitment to productivity improvement. Selected measures should be clarified by those who need to implement them (at all levels) and after their application continues to measure productivity and identify any further negative impacts. The achieved performance needs to be

analyzed and cyclically, in the same order, productivity improvement is continued to a satisfactory level. (We should always strive for better in realistic frameworks.)

### 3. Factors affecting construction productivity

#### 3.1. Barriers to Increasing Productivity

In order to increase productivity in construction, a better understanding of what is hindering productivity growth is needed (Green, 2016). Progress is possible but problems that hinder a significant increase in productivity in the construction industry and in contractors are deeply rooted, sometimes linked to culture (Horner and Duff, 2001). The specific characteristics of the construction industry, which is why productivity is always lower than that of industrial production, is the uniqueness of the construction projects (the impossibility of serial production), the need for workers, equipment and machines during the work to frequently change the workplace on the site (impossibility of chain production, sequencing), outdoor work (exposed to weather conditions) and many different types of work with different quantities (require different occupations workers and unequal loads) and numerous suppliers and subcontractors. Table 1 lists some other important obstacles that make it difficult to increase the productivity of contractors, recognized in foreign research studies and the reasons that stand out in Croatia today (according to the mentioned sources, data presented in public media and interviews with experienced experts in building practice).

Table 1. Obstacles to increasing productivity in construction

Obstacles identified in foreign research	Obstacles detected in Croatia
<ul style="list-style-type: none"> <li>- Fragmentation and often contradictory, partial interests of construction project participants (in relation to these opposing relationships in contracts) (Horner and Duff, 2001), (Attar <i>et al.</i>, 2012);</li> <li>- Instability due to the uncertainty of contracting jobs (Green, 2016);</li> <li>- Work-intensive industry (Green, 2016);</li> <li>- Insufficient focus on the workforce (Attar <i>et al.</i>, 2012);</li> <li>- Insufficient investment in education/training (Adrian, 2008);</li> <li>- Lack of baseline productivity data, ie lack of comparative references (de Araujo <i>et al.</i>, 2013);</li> <li>- Ineffective management (Attar <i>et al.</i>, 2012);</li> <li>- Lack of real commitment to continuous improvement (Horner and Duff, 2001), (Attar <i>et al.</i>, 2012)</li> </ul>	<ul style="list-style-type: none"> <li>- Lack of construction workers in the labour market;</li> <li>- Older workers (as well as the entire population);</li> <li>- Lower than average wages in construction;</li> <li>- The need for extended working hours during the construction season;</li> <li>- The inadequate school system for craft workers;</li> <li>- Poor education of engineers for knowledge other than technical (Medanić, 2005);</li> <li>- Insufficient lifelong education of construction engineers;</li> <li>- Very few large companies - predominantly small and medium-sized enterprises (Lovrenčić and Butković, 2010) with insufficient human resources to improve;</li> <li>- Insufficient research and inadequate cooperation between construction operatives and scientists</li> </ul>

An additional aggravating circumstance is difficulty in measuring productivity in construction (Horner and Duff, 2001), (Attar *et al.*, 2012) and the interconnectedness of different impacts, which makes it very difficult to precisely quantify certain influences.



### 3.1 A review of factors that have been identified to have a critical impact on productivity in construction

Exploring, identifying, and evaluating issues affecting labour productivity are key for managers on a project (project managers, site managers, construction company leaders, etc.) in their efforts to improve labour productivity. (An example of a model that helps managers in project management success is shown in Figure 2.) Knowing the factors that most often have the greatest impact on productivity is essential for preparing a strategy for reducing inefficiency (Jamadagni and Birajdar, 2015), ie to determine the focus of the required measures precisely to address critical factors from the initial stages of planning the construction (Gundecha, 2012).

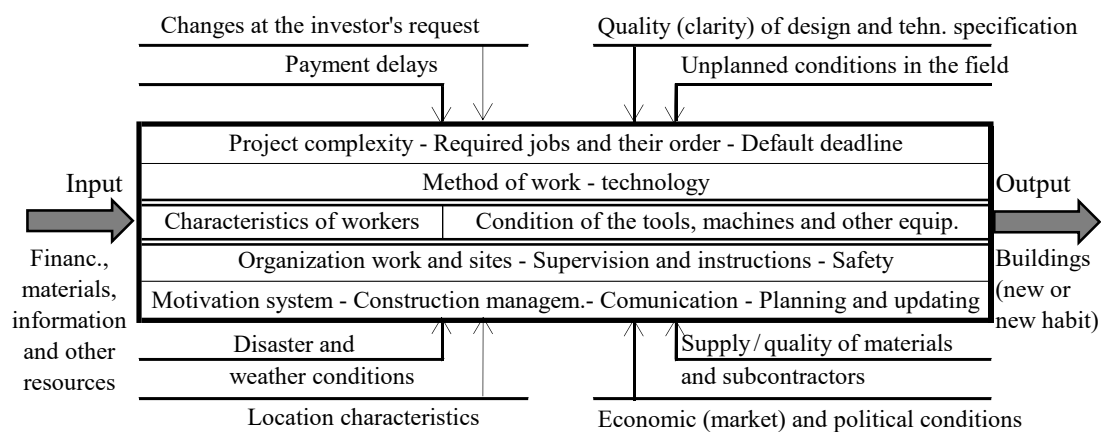


Figure 2. Influence factors on the system contractor on construction projects

So far, a large number of surveys have investigated the significance of over a hundred different basic factors affecting labour productivity. In these studies, based on literature and consultations with experts, the lists of influential factors were evaluated by the competent persons according to the size of the influence, and sometimes the frequency. The results of the examinations show that the influential factors differ depending on the region/country, the type of work required, ie the project (eg. housing or road construction, new building or maintenance/reconstruction), clients, material suppliers (Green, 2016) and the contractor company (size of company) and the working group (Halligan *et al.*, 1994).

Table 2 is an overview of the factors that have been ranked among the top five, according to the results of 17 previous studies in 15 different countries (41% in the EU and USA). The researches included in Table 2 are arranged chronologically: A - (Oštarijaš, 1986), Croatia; B - (Horner *et al.*, 1989), UK; C - (Vavra and Synek, 1994), Czech Republic, rating for medium-sized companies; D - (Kuykendall, 2007), USA; E - (Rivas *et al.*, 2011), Chile; F - (Gundecha, 2013), USA; G - (Jimoh *et al.*, 2013), Lagos, Nigeria; H - (Robles *et al.*, 2014), Spain; I - (Sherif *et al.*, 2014), Egypt; J - (Enshassi, 2014), Palestine; K - (Abrey and Smallwood, 2014), JAR; L - (Durdyev, 2014), N. Zealand; M - (Tahir *et al.*, 2015), Pakistan; N - (Joseph and Shankar, 2015), India; O - (Bekr, 2016), Jordan; P - (Sandeep and Mukesh, 2017), Bhind, India; R - (Nguyen *et al.*, 2018), Vietnam.

Skills or education and experience are considered to be one of the most important factors in 59% of this survey, and three times the most important of them is the separate experience and education both of you. Nearly half of the survey among five of the most important factors

was the ranking of supplying building materials (availability on site) and supervision workers. Of the above-mentioned influential factors, the last three are connected to the actions of the clients or the designer, and everyone else is in the domain of the contractor (ie his management). Besides, the vast majority of other factors included in the research are among the most important, but not in the table (less than 18% of the examined studies), results from the management by the contractor. Some of them can be connected with the factors in Table 2, such as a low amount of pay (2x) and types of salary payment (1x) with motivation, clear assignment of daily tasks (1x) and site layout (1x) with building management skills, while resource management (1x) with both the management capabilities and availability of materials, tools and equipment.

No	Influential factors	Published research results (ranges)																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	R
1	Level of skill and experience of workers		X	X	X			2X	X	2X	X			X	2X			X
2	Supply of constr. materials			X		X	X		X		X	X				X	X	
3	Supervision - control		X	X					X	X		X		X		X		
4	Incentive program - Motivation		X	X	X			X		X								
5	Competence and managerial skills (style, communication, etc.)				X			X								X	X	X
6	Availability of tools			X		X	X		X									
7	Availability of equipment and trucks					X	X		X							X		
8	Safety/Accidents				X		X			X	X							
9	Planning / scheduling and unrealistic deadlines	X			X						X	X				X		
10	Payment delays								X	X					X		X	
11	Changing order during execution	X										X	X					
12	Clarity of design and technical specification	X							X						X			

Table 2. The most important impacts on labor productivity by research published from 1986 to 2018

In a pilot study (2018) of the opinions of site management and supervisors in Croatia all interviewed, among the most negative influences included clarity of design (insufficiently elaborate) and technical specification, and most respondents point out the lack of experience and worker characteristics (including education), poor motivation, poor resource management, lack of materials and delays paying investors. The regularity of salary, size of the salary and cash bonuses are one of the five most significant factors affecting labor productivity in Croatia according to Nahod and Knezović (2017), which covers only factors related to the motivation of workers.

#### 4. Measures to increase the productivity of contractors

##### *What measures can be taken*

Basically, productivity improvement can be achieved by reducing investment (inputs) to obtain the same output, increasing the production volume with the same investment or partly by reducing investment and partly by increasing production (Green, 2016) and it is also possible

to increase investment by increasing productivity, but to a degree greater than the value of the investment increase. Nowadays, a more interesting growth in output is no increase in inputs, which is precisely the definition of technological development, ie, productivity increase (Gelo and Družić, 2015). Green (2016) in the analysis of the potential for increasing productivity in UK construction is of the opinion that it is probably the best combination of investment cuts and increase in product volumes.

In order to improve the labour productivity on the realization of construction projects, a series of measures can be taken - from work study at the level of work operation to the Building Information Modeling (BIM) at the project level (covers both managerial and technological aspects and requires the involvement of all project participants from the initial phase) and Lean management at the level of the entire company's contractor.

At the project level and/or the company's contractor, measures to improve productivity can be undertaken by individuals (competent, experienced, with appropriate powers, motivated), such as site managers and project leaders. These are, as a rule, short-term measures with a rapid effect, oriented to the realization of particular, ongoing projects (Figure 3). Long-term measures are being taken at the state/construction industry level (creating conditions for improving productivity in a variety of ways - through a suitable education system, investment in construction projects, favorable loans and guarantees, facilitation/ support for employers, regulations and avoiding their frequent changes, the procedure of issuing permits, linking and collaborating with the contractors etc.) and at the level of certain companies (implementing a proper strategy for systematic loss reduction). Some measures can immediately give results, and some will take longer. For example, proper motivation can very quickly lead to high productivity growth, but certain motivation measures have a limited duration of effect on workers. Ensuring the necessary workforce with good qualifications and experience is the result of a long-term strategy for attracting, training and retaining such workers. However, at the realization of a particular project, such a workforce can be ensured by fast (but temporary) engagement of a particular crew of suitable features or subcontractors with high-quality workforce for the work to be done.

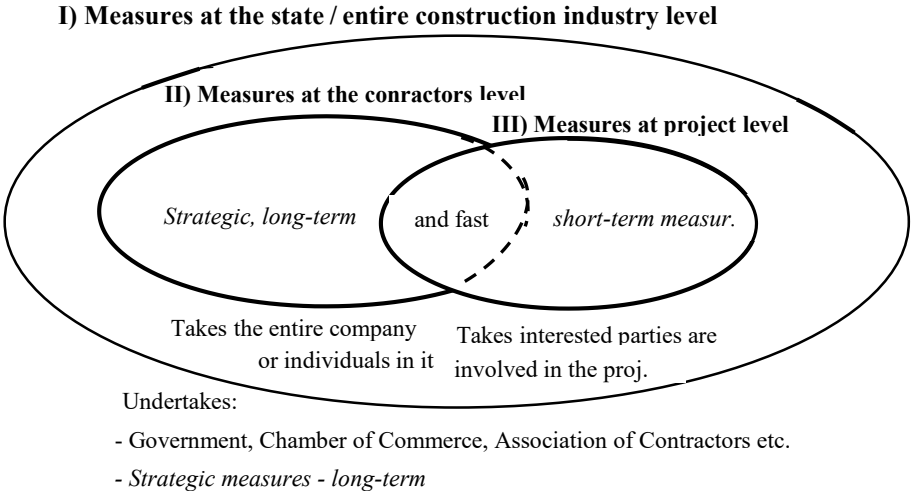


Figure 3. Levels of taking measures to increase productivity

According to the factors identified as the most significant in the impact of labour productivity, it can be seen that the measures for its increase are mainly geared to the choice, training, and motivation of the workers, safety at work and quality preparation/logistics and managing (including planning of works and resources, organization on the construction site, establishing good relations with workers and communication etc.) and regular, competent supervision. With skilled, better-trained workers for the job (no sense or being re-qualified), more work can be done in less time, without jeopardizing the quality of work (Ghate and Minde, 2016). Therefore, one of the biggest challenges facing construction industry in Croatia, like in many other countries, is the ability to provide-skilled workers (eg, the Construction Industry Institute noted this problem in the United States (Chapman *et al.*, 2010)).

Evident barriers and negative impacts on productivity indicate that the maximum can only be achieved by improving the performance of both contractors and clients (insight into high-quality project documentation - clear, elaborated designs and technical specifications, analyzing the project solution prior to the realization process in order to avoid subsequent changes, realistic planning of the budget and payments according to the dynamics of the works the realistic deadlines, providing all the necessary information in a timely manner, BIM, etc.) and the appropriate support of the state. Both the client and the state harm the contractor's poor performance, so it makes sense for their additional engagement in this regard to help the contractor. The government should consider investing in the training of the workforce required by construction, and then it may also be sought by the employers because well-trained workers will be more productive in the company. With a larger range of better skills, workers will have higher salaries, and with this, they will be able to repay a loan for their training (Dharani, 2015) and will pay higher taxes and thus return to the state they invested. With higher wages, a worker will be able to invest themselves in their further professional training, but it can also be done by the employer by binding them to a contract for their company.

According to Dai and other (2009) surveys, construction workers consider that most of the negative factors affecting their productivity can be solved by the site management. For example, appropriate changes in the look of workplaces affect work productivity, so properly deployed material on the construction site can in some cases reduce up to 50% of the time needed for execution (Ghate and Minde, 2016). Of course, there is always a need to improve what is flawed in the particular case and focus on what causes the greatest loss of time. External factors cannot be influenced by a contractor, but they should be attempted to adapt (implement fundamental principles of weather mitigation) to minimize their negative impact (Sukumar and Kumar, 2016), (Thomas and Ellis, 2017). Productivity as a result of the actions that cannot be avoided and the negative impacts that counteract positive measures are illustrated in Figure 4.

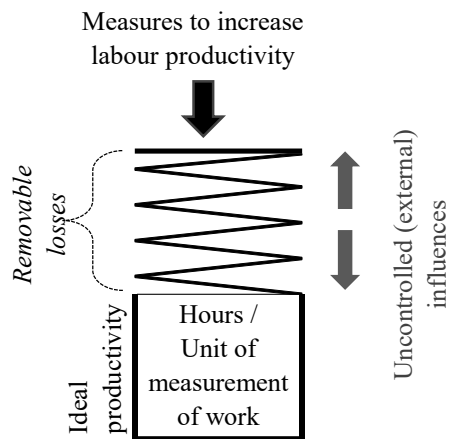


Figure 4. Impacts on productivity of contractors

We should try to identify examples of good practice (de Araujo, 2013) both in our company and beyond. In addition to considering negative impacts, it is desirable to examine possible positive impacts and be prepared to use them to increase productivity.

#### 4.2 Measures proposed on the basis of previous research

The ability to increase productivity by the contractor can be categorized into the following categories (Efimenko, 2008), (Porier *et al.* Jergeas, 2009):

- organization and management system,
- labor force (socio-economic and social-psychological measures),
- mechanization and automation (more advanced machines and their higher degree of use),
- new, more suitable materials and techniques.

Many kinds of literature (eg. (Rojas and Aramvareekul, 2003), (Efimenko, 2008) (Adrian, 2008), (Goodrum *et al.*, 2009), (Huang *et al.*, 2009), (Chapman *et al.*, 2010), (Malisiovas, 2010), (Sukumar and Kumar, 2016), (Porier *et al.*, 2016), (Green, 2016), (Uddin *et al.*, 2017) etc.) recommended to increase productivity using new, advanced technology (including prefabrication). However, some authors (such as for example, Rojas and Aramvareekul, 2003) consider productivity improvements as a matter of management alone, ie. consider that introducing new techniques or technologies may be necessary but not enough to improve productivity. If the relative increase in the cost of investing in new equipment and technology goes beyond the relative saving of labour costs and gains due to higher production it actually represents a productivity decline (Porier *et al.*, 2016). However, the available mechanization should be maximally exploited (Efimenko, 2008), (Attar *et al.*, 2012).

Table 3 gives an overview of measures to increase the productivity of contractors by the authors of previous research.

Table 3. The measures that researchers recommend to increase the productivity of construction work and the factors they are positively impacting (marked by their ordinal number from Table 2)

Measures that increase productivity	Research in which they are recommended	Factors to which measures act
Appropriate training of workers (providing training and development)	(Rowlinson and Proctor, 1999), (Horner and Duff, 2001), (Attar <i>et al.</i> , 2012), (Dharani, 2015), (Green, 2016), (Sukumar and Kumar, 2016), (Buli, 2017)	1
Managing materials (detailed procurement schedule, automatic materials tracking) - timely supply of material in sufficient quantities	(Rowlinson and Proctor, 1999), (Adrian, 2008), (Attar <i>et al.</i> , 2012), (Gundecha, 2012), (Thomas and Ellis, 2017), (Shinde and Hedao, 2017)	2
Managing resources and ensuring the availability of resources	(Shehata and El-Gohary, 2011), (Ghate and Minde, 2016), (Uddin <i>et al.</i> , 2017)	2, 6, 7
Enough tools in working order	(Dharani, 2015), (Jamadagni and Birajdar, 2015)	6
Equipment management, ie equipment planning in advance	(Rowlinson and Proctor, 1999), (Adrian, 2008), (Attar <i>et al.</i> , 2012), (Sukumar and Kumar, 2016)	7
Efficient planning and proper time schedules	(Horner and Duff, 2001), (Adrian, 2008), (Efimenko, 2008), (Naoum <i>et al.</i> , 2009), (Valverde-Gascueña <i>et al.</i> , 2011), (de Araujo <i>et al.</i> , 2012?), (Aziz and Hafez, 2013), (Dharani, 2015), (Sukumar and Kumar, 2016), (Green, 2016), (Thomas and Ellis, 2017), (Sukumar and Kumar, 2016)	2, 6, 7, 9 (and crowded areas of work, mixing work groups)
Update plans according to the changes	(Valverde-Gascueña <i>et al.</i> , 2011)	2, 6, 7, 9
Regular, frequent meetings for progress monitoring	(Horner and Duff, 2001), (Uddin <i>et al.</i> , 2017)	9
Timely, competent supervision at the place of execution with clear instructions	(Rowlinson and Proctor, 1999), (Goodrum and Haas, 2002), (Valverde-Gascueña <i>et al.</i> , 2011), (Attar <i>et al.</i> , 2012), (Aziz and Hafez, 2013), (Dharani, 2015), (Jamadagni and Birajdar, 2015), (Sukumar and Kumar, 2016)	3 (and mistakes and rework)
Less workers per supervisor	(de Araujo <i>et al.</i> , 2012)	3
Applying an appropriate leadership style - (use of modern management techniques such as socio-techno-	(Rojas and Aramvarekul, 2003), (Efimenko, 2008), (Naoum <i>et al.</i> , 2009), (Gundecha, 2012), (Dharani,	5

managerial approach, friendly relationship with workers and etc.),	(2015), (Thomas and Ellis, 2017), (Buli, 2017)	
efficient management system to communicate, coordinate and control	(Naoum et al., 2009), (de Araujo et al., 2013), (Uddin et al., 2017)	5
Motivation through incentives and other programs (creating the work environment that can motivate - awarding the best worker etc.)	(Rowlinson and Proctor, 1999), (Efimenko, 2008), (Naoum et al., 2009), (Gundecha, 2012), (Attar et al., 2012), (Dharani, 2015), (Jamadagni and Birajdar, 2015), (Sukumar and Kumar, 2016), (Buli, 2017)	4 (Motivated workers are more active and have a greater output)
On time payment to the workers	(Attar et al., 2012), (Jamadagni and Birajdar, 2015), (Sukumar and Kumar, 2016)	
Safety program (training and safety work meetings)	(Rowlinson and Proctor, 1999), (Adrian, 2008), (Gundecha, 2012) (Dharani, 2015), (Green, 2016), (Sukumar and Kumar, 2016)	8 (Labour feel secured at safe sites and tend to produce more)
Provide sufficient lighting on the construction site and place of work	(Gundecha, 2012)	8 (Less chance of injury and quality, faster work)
Keep the cleanliness of the workplace	(Valverde-Gascueña et al., 2011)	8 (Less chance of injury and faster job search)

Except the productivity increase measures listed in Table 3, authors of previous studies recommend measures concerning workers and organizations of the construction site: try to hire as many workers as possible for a longer longer duration (Dharani, 2015), avoiding overtime (Horner and Duff, 2001), (Jamadagni and Birajdar, 2015) and overlapping work of more than two crew (different occupations) in the same space, organizing consecutive/cyclical performance of work tasks (Valverde-Gascueña et al., 2011), implementing appropriate measures to maintain work discipline (Attar et al., 2012), (Gundecha, 2012), provide the necessary contents on site (for workers, waste area etc.) (Dharani, 2015), (Valverde-Gascueña et al., 2011) and optimal layout of the site (material easily accessible and close to the building where it is built) (Attar et al., 2012), (Gundecha, 2012), (Sukumar and Kumar, 2016) etc.

#### 4.3. Increasing productivity by Lean managing contractors

Although designed for factory production, the Lean concept is appropriately adapted to the application in construction. There is no formula to implement Lean in the company, but it is necessary to notice the losses and to eliminate them with the help of the appropriate tools (techniques) (Piškor and Kondić, 2010) and accept implementing as a long-lasting process.

Based on the Cost case study in Poland Nowotarski *et al.* (2016) found that the costs of introducing Lean Management were far less than the savings that the contractor achieved with him.

Lean in contractor companies can bring advantages such as reduced administration, improved workflow, improved teamwork, reduced inventory, lower material consumption, better organization of workplaces and space, shorter work time and higher product quality and through this certainly higher productivity. Swefie (2013), according to twelve research sources in five countries (US, Brazil, Nigeria, UK, and Sweden), for the period 2001-2013, states that using Lean approach and Lean techniques in constructions has reduced the project duration of 17 - 79%.

For example, 5S techniques can be successfully used in many construction processes because to the low financial costs required for its implementation (Nguyen, 2015), and due to the frequent types of construction losses, Croatian contractors could be very useful Just-in-time and Gemba and Kaizen's approach.

## **5. Conclusion**

Despite deep-rooted problems and many factors hindering construction productivity growth, the misconception is that productivity increases cannot be achieved, as evidenced by documented successful examples (published case studies). By analyzing measured productivity and detected delays (loss of working hours), appropriate action measures can be designed to avoid or reduce productivity losses. In order to be effective measures of action, they must always be customized for each concrete case. (The published results of research by contractors can only be used as backgrounds and guidelines because within the construction industry there are great differences.) In order to determine which measures may be most effective and what needs to be taken primarily, it is necessary to identify impacts on productivity and to rank them by importance. There is a need to improve what is lacking on the construction site and companies, but paybacks must be taken into account. It should also be prepared to encourage and exploit favorable opportunities.

In view of the observed obstacles and factors that have the most serious impact on the productivity of construction work in Croatia, there is a need for clients and government involvement in the ability to increase the productivity of the contractor. For this reason, all participants in the realization of the project should be encouraged to increase the performer's productivity in the common interest (gives a positive contribution to achieving the goals of both the clients and the state).

There is a need to invest in appropriate education/training of workers and management, as they often make the most contribution to achieving the productivity of contractors. It is recommended cyclical implementation of improvement measures in the contractor's system, using Lean approach and techniques. If the measures to increase productivity are successfully implemented, the increase achieved allows for avoiding the need for overtime or excessive workload and overcrowding (which further reduces worker productivity (Horner and Duff, 2001).) Eliminating unnecessary time losses and increasing productivity reduces the cost of a contractor, increases its competitiveness and leads to greater investor satisfaction.



Probably, further improvements and new negative impacts are likely to be possible, and even after productivity increases, contractors should continue to monitor (measure) productivity on projects they realize.

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# Strategic Engagement of Local Communities on Large-Scale Infrastructure Projects

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## **Abstract:**

It is increasingly important that project managers develop greater capabilities to better manage the social, cultural, political, environmental and economic impacts on proposed construction projects. On large-scale infrastructure project, the local community is an important stakeholder as they are often most directly impacted by a project. Effective and meaningful engagement of the local community is critical to get them on side and to ensure local buy-in on the project. While a rich body of research and intellectual frameworks exist in the fields of urban geography and planning to better understand and manage community concerns during the pre-development approval stages of new projects, current theoretical frameworks guiding community engagement during the construction phase are inadequate. Within this context, this research aims to better understand strategies adopted by the project teams to engage with local communities so as to capture lessons learnt to apply to future projects. A case study approach utilizing interviews and documentary analysis of a large-scale infrastructure project in Queensland, Australia is presented. The findings suggest that proactive, strategic and meaningful engagement of influential individuals and groups can go a long way towards building localised support and acceptance of the project.

*Keywords: community, engagement, infrastructure projects, impacts*

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## **1. Introduction**

Engaging the local community on projects that can directly impact them makes good business sense as it reduces the likelihood of project delays resulting from localized protest. This is particularly important during the construction phase of large infrastructure projects when impacts are most pronounced. Good project management practices and most government planning regulations require on-going community engagement over a project's entire lifetime, not just during the planning stages of projects (Cleland and Ireland 2007; PMI 2017). However, there is a common and problematic assumption underpinning construction project management literature that local communities have been adequately consulted during the pre-development approval phases of projects and that no further consultation is required during the construction phase (Close and Loosemore, 2014; Teo and Loosemore, 2011; Murray and Dainty, 2009). Yet in reality, residual community concerns from pre-development phases often continue into the construction stages to develop into costly and long-standing disputes and increasing the likelihood that the project may not be delivered on time, on budget or at all (Sharpe, 2004; WRI, 2007).

Engaging communities in an effective manner is particularly important on large-scale infrastructure projects (Buckley, 2012), which are often built in areas of high urban density. Large-scale projects often have a large construction footprint, are expansive endeavours, can take years to build, and have the potential to negatively affect the local community in which the project is based through noise and dust pollution and other project impacts (Flyvbjerg, 2014). Effective and meaningful engagement of the local community is critical to get them on side and to ensure local buy-in on the project, and is one of the key indicators of project success (Toor and Ogunlana, 2010). The local community is defined in this research as a geographic- or location-specific sense of belonging or attachment to a place that arises from a commonality of social experiences or sense of familiarity among people or groups who live, travel, or work in the area (Cater and Jones, 1989; Stedman, 2003). Smith et al. (2014) suggest that the local community involvement in a project share a number of common attributes that give them unique status as a project stakeholder by recognizing that:

- the community's close proximity to the project accords them social, cultural and physical ownership of the project;
- the project activities occur on or in close proximity to local community members' physical domain;
- the project has a disruptive impact on some aspect of the community's existence;
- communities have to live with both the positive and negative impacts of the project.

Zhu (2015) and Walsh et al. (2017) suggests that as a directly affected stakeholder, local communities will seek on a fundamental level to exercise some control of their immediate environment, and have expectations and needs that will need to be managed by the project team, particularly during the construction process when the impacts are most pronounced. There is an urgent need for robust engagement processes to guide how the project team can more effectively engage with the local community for project success. While a rich body of research and intellectual frameworks exist in the fields of urban geography and planning to better understand and manage community concerns during the pre-development approval stages of new projects, current theoretical frameworks guiding community engagement during the construction phase are inadequate.

Within this context, the primary aim of the paper is to better understand strategies adopted by the project teams to engage with local communities during the construction phase of large-scale infrastructure projects. The project will capture community engagement lessons learnt and contribute towards creating a body of knowledge to better equip building professionals with the skills needed to better engage with local communities, so as to deliver infrastructure projects on time and budget, and to facilitate its acceptance within the local community.

## **2. Community engagement on projects**

Community engagement is defined in the context of this research as: "... the process in which a proponent builds and maintains constructive relationships with local communities impacted over the life of a project..." (WRI, 2009: 3). Engaging communities on projects is often a challenging process in the construction phase for a number of reasons. First, as stated previously, there is an underlying belief that community engagement is not the responsibility

of the project team, but that of planners (Teo and Loosemore, 2011; Murray and Dainty 2009). This reluctance to engage was reported in Close and Loosemore's (2014) research which found that construction professional with direct responsibilities for community engagement on projects perceived local communities as a problematic stakeholder, and a liability rather than an asset to the project. These professionals are more likely to report negative past experiences of community engagement and a reluctance to engage with communities on further projects. Provision of information was seen as empowering communities and was only done on a as needed basis. There was no real intent to consult or engage, and they adopted a reactive rather than proactive strategy to community engagement.

Dudley (1993) suggests that community engagement processes can be used as both a tool and a goal. When used as a tool, it has the effective of perpetuating a 'us vs them' divide, whereas when conceived as a goal, it can "transfer power to the community more equitably" (Dudley 1993: 8). A central tenant here is the concept of power sharing or delegation, and the extent that community input, concerns and aspirations for the project is genuinely reflected in project decision making. Nabatchi and Leighninger (2015) suggest that there is often a struggle for power particularly in the planning phase of a project when key planning and design decision are made. Indeed, while community engagement is often mandatory as part the project approval processes, there is very little evidence to suggest that true and meaningful engagement exists and where communities input had affected project outcomes (Stewart and Lithgow 2015). The dominant level of engagement is suggested to sit at 'consultation' with communities often asked to approve predetermined plans (OECD 2001; Nelson et al. 2008 as cited in Stewart and Lithgow (2015). While there is some anecdotal evidence that community engagement is occurring during the construction stages of some large-scale infrastructure projects (Close and Loosemore, 2014), it is not clear what these strategies are and their effectiveness, which makes this research exploratory in nature.

### **3. Method**

A single case study approach was utilized to better understand strategies adopted by project teams to engage with the local community during the construction stage of large-scale infrastructure projects. Case studies are the research strategy of choice as they provide a rich, meaningful and elaborate account of engagement strategies as used by the project team, thereby allowing for an in-depth assessment of strategies used within the case study context (Yin, 2018). The use of single case study was supported by Flyvbjerg (2006) who suggests that single case studies are advantageous in producing rich, context-dependent knowledge that are valuable as stand-alone narratives of the phenomena under investigation. While a key criticism of the single case study approach was its lack of generalizability, the greater depth of study achieved through single case studies improved the reliability of the findings produced. Qualitative research is compatible with the case study approach because of its flexible nature and inherent openness that facilitates the deeper generation of insights that complements the exploratory nature of this research.

The case study was a A\$56 million civil construction project located in Queensland, Australia, and involved design and construction works to convert an existing pedestrian mall into a vehicular roadway as well as the construction of a new city centre and a public transport

hub. The project had a 2-year duration and the client was a local government authority. The project was controversial as construction works had to proceed in a busy and operational city centre with a diverse range of retail shops, cafes and businesses. Community concerns during the construction phase ranged widely from loss of business income, loss of tenants, loss of parking, loss of utilities and services, lack of business and customer access, safe design, unattractive design, construction-related impacts such noise, dust, obstructions and visual impacts, and increasingly negative perceptions of the project. The contractor was aware of significant community concerns and perceived impacts from the planning phase that could transition into the construction phase and had taken that into account when tendering for the project, as one of the interviewees stated:

*“... it was in the papers a long time... (when) our company was tendering on it, and it was one of those jobs that I thought would be a very high risk job....”*

Individual semi-structured interviews were conducted with key project team members who worked on the case study project. Following Blee and Taylor (2002), the interview sampling was guided by the principle of completeness and refers to the deliberate selection of interviewees who are knowledgeable or have specific experience of the topic, with new interviewees added to the sample as needed. As the project is concerned with the strategic nature of community engagement strategies used on the project, the sampling was limited to a very small pool of individuals who were senior and key members of the project team who had direct input in decision making processes relating to community engagement, and the choice of strategies adoption. Further, key project team members are of interest as they often have the most direct experience of, and are ultimately responsible for engaging local communities in the construction stage. The sampling resulted in four interviews conducted with key members of the project team who held roles such as project manager, community and stakeholder manager and senior project manager. The small sample size obtained was mitigated by the “information power” (Malterud et al., 2015: 1753) each interviewee held as a key member of the project team, such that “...the more information the sample holds, relevant for the actual study, the lower the number of participants is needed”.

Semi-structured interviews are the tool of choice as they facilitated a guided but flexible interview process useful for gathering rich, descriptive and detailed data that is suitable to the exploratory nature of this research. An interview guide in the form of suggested questions was developed and asked questions relating to the community engagement process, and strategies used in community engagement. A thorough documentary review of all available published information on the case study project relating to community engagement was used to produce a timeline of project events and served as a tool of reference during the interviews and provide context to the interview analysis. The interviews took approximately 45 minutes to two hours each and were tape-recorded and transcribed for subsequent analysis.

Interview transcripts and documentary data was analysed using the text mapping software Leximancer which produces a concept map of key data themes and their relationships. Leximancer measures the presence and frequency of concepts while structural analysis explores how identified co-occurrence of concepts as they relate to each other in a body of text



(Leximancer 2016). The output is displayed on a concept map that provides a bird's eye view of key data themes and their relationships. Each map depicts individual concepts that emerged as important from the data and are represented by individual nodes which are grouped into themes by circles. Related concepts tend to occur close to each other, with the size of a concept reflecting its connectedness to others, while similar colours indicate similar themes. An example of a concept map is shown in Figure 1. Documentary analysis of the case study was also used to integrate and provide a richness of explanation for understanding the different key concepts and themes highlighted in Leximancer to reveal key findings and insights.

#### 4. Discussion of Results

The research revealed that community engagement served different functions during the planning and construction phases of the project, as shown in Figures 1 and 2.

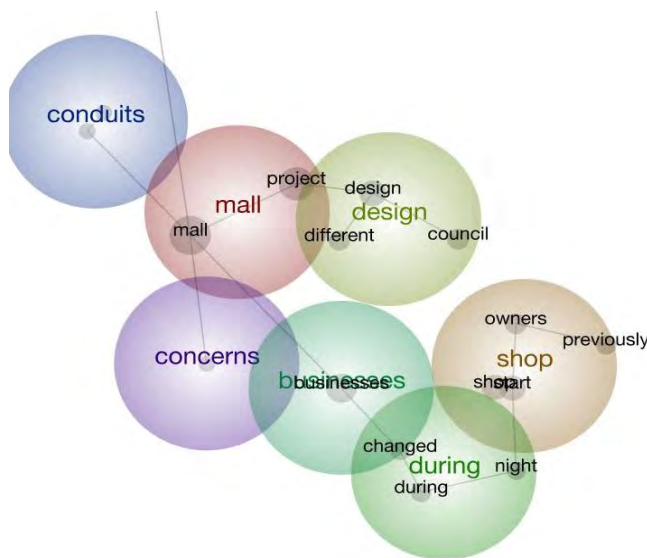


Figure 1. Map of thematic group of concepts for community engagement during the planning phase

In Figure 1, a purposive and exhaustive community engagement process was undertaken during the planning phase using multiple methods of engagement to ensure effective capture of community opinions of the proposed project and was used to inform project decision making:

“... we did a big media launch... (had) open project briefings (for) the public... (and) different briefings for the shop owners... (and) said to them, ‘this isn’t set in stone, we are here to get your thoughts (on the location of) car parking, loading bays, taxi ranks, post boxes etc. for businesses... everyone had the opportunity to have their input... so they would come back with all their points, 95% (of which) we could meet. And so it’s a big win-win.”

“... (in) the planning phase, we sent concept plans to every building and shop owner... (and held) open sessions (together with) project managers and design team... (to) answer their questions and go through the designs... So they (owners) had valuable advice for us that we took on board as well, and they were easy to engage with...”

The robust and inclusive community feedback process adopted gave the project team important insights into the practical and safe use of the redesigned space, particularly from the

perspective of affected businesses. The project took on board feedback provided and worked to incorporate the majority of changes suggested into the design to promote its acceptance by the community. This was important as the community engagement process revealed a diversity of community opinions on the proposed project:

“... some of the main concerns (are) of revenue (loss) during (the) construction period... (and) a lot of people just don't like change... but you did have a certain amount of people who were happy to see an upgrade as well... they needed change to get their businesses going because they were struggling at the time. So, it was probably next to 50-50...”

“I think the community in general was really excited about the project because it (the street) was really poorly used, unsafe. People didn't want to come down here. So, everyone was keen to have it done...”

Community sentiments over the proposed project was suggested to be divided equally between opposition and support, with a section of the community expressing support for a much needed project to upgrade the city centre. There was however, also some opposition to the project which as driven in part by a resistance to change among affected businesses who were concerned about construction-related impacts and business viability during that period.

Figure 2 shows that as the project progressed into the construction phase, the focus of community engagement was on mitigating the impacts of construction on locally affected businesses which ranged from noise, dust, customer access and business viability concerns:

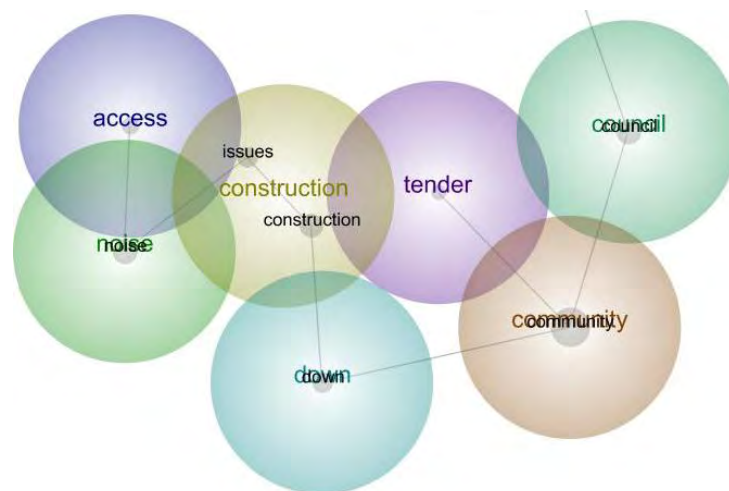


Figure 2. Map of thematic group of concepts for community engagement during the construction phase

“... they are pretty much what you would expect... the impacts of construction, loss of business, the access for customers to their businesses during the project, noise, dust... Plus specific concerns for specific businesses...”

“One of the big things is the entrance to their shops... we would work at night time to pour the concrete so they could come back the next morning (and) it wouldn't be interfering with them... we always showed, that we're trying to work with them, (even though) sometime we couldn't... (By) talking with them regularly, they would say we need this access at certain times... so we give them access...”

While the nature of impacts and concerns raised by affected businesses are those typically associated with the construction process, individual businesses often had specific needs that had to be managed on a case-by-case basis by the project team. By genuinely listening to affected businesses, the project team was able to better understand the underlying concerns and needs of the business community, for whom a key priority was to ensure potential customers had on-going access to affected businesses.

Figure 3 shows that across both phases, there was evidence of a proactive and inclusive community engagement strategy to engage early, meaningfully and frequently with affected businesses to keep them informed of the project:

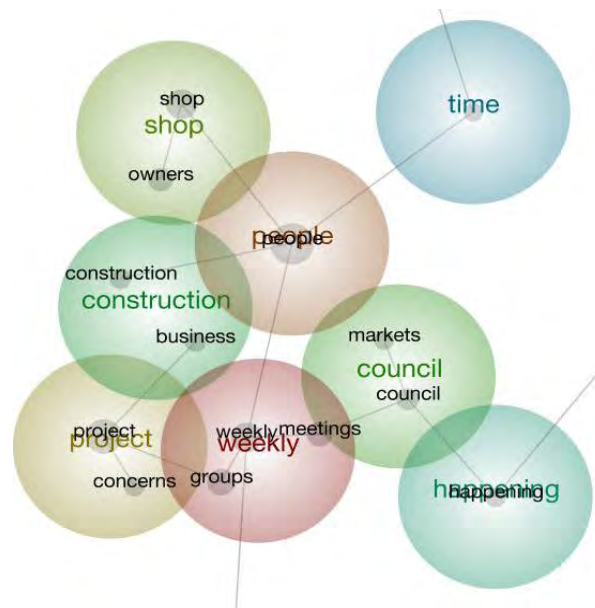


Figure 3. Map of thematic group of concepts for community engagement strategies

“... the whole communication strategy was the key to the success of the project... just by keeping them heavily involved and even if you're giving them too much information. They always knew where we're going to be working next week, (and) if something changed... (they would) let them know...”

*“(publication: weekly updates) was a combination of two things: the questions and answers that have come up on the weekly meeting... (and) any events... (or) particular promotions... And then it would have the two weeks look-ahead for each section of the construction job... (and) the contact details to get in touch with us.”*

“...(at the weekly meetings) an update of where we are at and where we are going and if there's been any delays or changes... They were vital because people had an opportunity to ask questions, air their concerns, and we could answer them on the spot. Also, what happened was (with) the regular moaners (was that) other people at the meetings would say to them ‘That's not true, that's not happening’, so we built up support for what we were doing that helped with the community (that did) not support (the project).”

*“... once we started construction, the Chamber of Commerce had engaged with all the shop owners and businesses, and they gave to us a risk profile, and (told us) some of the issues... they were one of our key stakeholders because they hear from*

*all the businesses all the time... We (also) engaged with the community group(s)... we had great relationships with and their feedback was valuable.”*

Strategic and on-going engagement with the affected businesses, utilizing project publications (weekly updates) and face-to-face meetings, sometimes on a daily or weekly basis, formed part of a purposive and successful strategy to ensure early and timely delivery of information in a way that could be understood by them. Over time, the community support that had built up for the project served as a self-correcting tool to address general misperceptions about the project. The strategy to engage key community and business groups, who had varying degrees of interests and influences within the community, was also instrumental in getting the community on board with the project. A complimentary strategy was also adopted to generate community goodwill and encourage local buy-in of the project by affected businesses and the wider community:

“... we (the contractor) really pushed all our staff (during the project) – we had up to 120 people there a day - to shop there and to buy (there)... like if you’re going to buy some clothes (or) your lunch or anything, you use the shops there. And that gave them that extra (business) – they might have lost some people but they gained all the construction workers and especially the food shops; they said it’s the busiest they've ever been.”

“(The contractor) did a big Christmas promotion... in the newly opened section of the redevelopment and we were handing out dollar vouchers that people could spend in those shops that were part of the construction area... we printed posters and a brochure that went out to the whole wider community and it (was) part of the advertising (and) TV ads that promoted this campaign. The whole thing cost (the contractor) around A\$10,000 dollars... (but) the shopkeepers loved it because people were going to the shops to spend their vouchers and then spend some more. And they could see that the contractor was giving something back to the community... (and) they got a lot of brownie points from it.”

Ongoing evaluation of the community engagement process through regular survey, suggested a high level of community satisfaction with the project, and that the engagement strategies were having a positive effect on changing community perceptions of the project:

“The council, they wanted to be able to evaluate that we had increased awareness and understanding of the project... (we conducted) a baseline survey at the start and then bimonthly surveys where (we) went around (to) each shop and we had about six or seven questions and filled them in. We have a software where we could enter the data and come up with charts. So, it was progressing to see whether they are happy with the information received, did they understand it, were we minimising the construction impacts and we asked them (to) rate (our) performance. So that was giving an ongoing evaluation.”

“So, we’d get the feedback from the stakeholders of how we’re performing... and we had KPIs on it as well as financial gains or losses... (so) we had an incentive to make sure that we’re ticking the boxes and we rated very high all through that. We achieved our 100 percent... (it seemed) to work quite well.”

## 5. Conclusion

The aim of the paper was to better understand strategies adopted by the project teams to engage with local communities during the construction phase of large-scale infrastructure projects. Very little is currently understood about the nature of strategies utilized to engage local communities, particularly during the construction phase of projects, and their effectiveness. Through an in-depth single case study of a large-scale civil construction project, the findings suggest that early, proactive, strategic and meaningful engagement of influential individuals and groups can go a long way towards building localised support and acceptance of the project.

Overall, a proactive and inclusive approach to communication allowed the project team to engage early, meaningfully and frequently with affected businesses to identify suitable timings to schedule construction works, to ensure businesses had on-going access to their shops and also assisted in minimizing construction and business impacts. The project team utilized a combination of face-to-face meetings and project publications to facilitate the widespread dissemination of project updates to affected businesses and beyond. A broad strategy of general engagement was also adopted to sell the project and to generate community good so as to encourage local buy in of the project. A concerted effort by the contractor to encourage employees and subcontractors to buy locally also worked well to boost the bottom line of affected businesses.

The lessons and implications for project managers are three-fold. Firstly, it is clear that the benefits of engaging communities outweigh the risk and challenges of doing so through early issue identification, complaint minimization, and to build trust with community. Secondly, it is important that engagement efforts be inclusive and utilise multiple outreach methods to ensure effective capture of community opinions on the project. However, engagement efforts need to be meaningful and community feedback incorporated into project decision making where possible to facilitate local buy-in of the project by the community. Thirdly, there was a need to build community good will to encourage local acceptance of project, build project legacy and to achieve a good practical outcome for affected communities and beyond. For contractors, the good will generated can include positive reputation benefits which offered competitive advantages when bidding for future work, particularly with government organizations.

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# Corruption in the Egyptian Construction Industry

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## Abstract:

Construction is one of the most susceptible industries to corruption worldwide. The presence of corrupt actions within construction undermines project management strategies and impacts vital project and industry elements, costing the industry billions worldwide. NGO reports suggested that Egypt has high levels of corruption; however, there is a lack of academic research in this area which investigates corruption in Egypt, and specifically in Egyptian construction. Nevertheless, construction corruption studies were carried out in several other countries, which informed this paper. The paper aims to provide a novel account regarding corruption in Egypt and its construction industry, focusing on corruption levels in the industry, the underlying causes and impacts of corruption, and identifying corruption forms within construction project stages. To achieve this, firstly an extensive literature review was carried out to present a corruption definition as well as discussing corruption in construction, and corruption in Egypt. Secondly, 18 semi-structured interviews (40-90 minutes each) were conducted among Egyptian construction professionals operating at strategic, tactical and operational levels, who represent contractors, clients and engineers from the public and private sectors. Thematic analysis of the recorded transcripts revealed corruption has become a part of the Egyptian culture caused by need, greed and lack of ownership. There is a deeply rooted corruption problem in Egypt's construction industry, where public sector projects are the most vulnerable to corruption. Furthermore, the data suggests corruption impacts are experienced at the project, industry, and the country levels. Despite its impacts, construction companies perceive corruption as part of doing business.

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**Keywords:** *corruption; construction; Egypt*

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## 1. Introduction

As one of the most dynamic industries in Egypt, the construction industry strongly affects the country's economy; keeping it afloat during times of global recession (Khodeir & Mohamed, 2015). In addition, the industry provides a vast range of job opportunities to millions of Egyptians (ElGhamrawy & Shibayama, 2008). However, the Egyptian construction industry was heavily impacted due to the rapid changes the country has gone through following the political and economic upheaval surrounding the 2011 uprising (Salah, 2011).

One of the main issues that ignited the 2011 uprising was widespread corruption (Abdel Meguid et al., 2011). Joya (2011) reports that the monopolisation of core industries drastically increased in the years leading to the uprisings. This includes steel and cement manufacturing,

which are the foundation of the Egyptian construction industry. However, the fact remains that Egypt has yet to become less corrupt (Mourdoukoutas, 2017). GAN Integrity (2018) suggests that corruption in Egypt goes beyond certain political leaders or public officials; it is embedded in the culture itself. The Egyptian culture has become one of facilitation payments and powerful connections.

The global construction market is suffering from an increase in corrupt activities (Gunduz & Onder, 2013; Mukumbwa & Muya, 2013; Le et al., 2014). Corruption can affect the construction industry on multiple levels; it can damage individual projects, whole companies, and entire economies (Le et al, 2014). In addition, corruption costs can amount to 10% of the industry's global market value (Kyriacou et al., 2015). There is little information regarding corruption in Egypt, and its construction industry. However, since Egypt possesses high levels of corruption, and that corruption is an issue facing the global construction industry, it can be hypothesised that the Egyptian construction industry suffers from high levels of corruption.

This paper aims to provide a novel account of corruption in the context of the Egyptian construction industry. This is carried out by exploring corruption as a concept, and providing explanations on the state of Egypt and its construction industry; followed by an investigation of construction corruption in the Egyptian context with reference to its causes, forms, and impacts.

The paper is divided into 5 sections with this introduction being the first. The second section provides a literature review that presents previously published work relating to the issues raised in this paper. The literature review provides information regarding the complexities of defining the concept of corruption, corruption in Egypt, the characteristics of the Egyptian construction industry, corruption in the construction industry, and a conclusion that summarised the findings from secondary resources. The third section of this paper presents a detailed description of the primary data collection process. This includes the data collection method used, a description of the sample used, and how the data was managed and analysed. The fourth section presents and discusses research findings relating to the identified research areas. The fifth section concludes the paper, and provides plans for future research.

## **2. Literature Review**

### *2.1. Defining corruption*

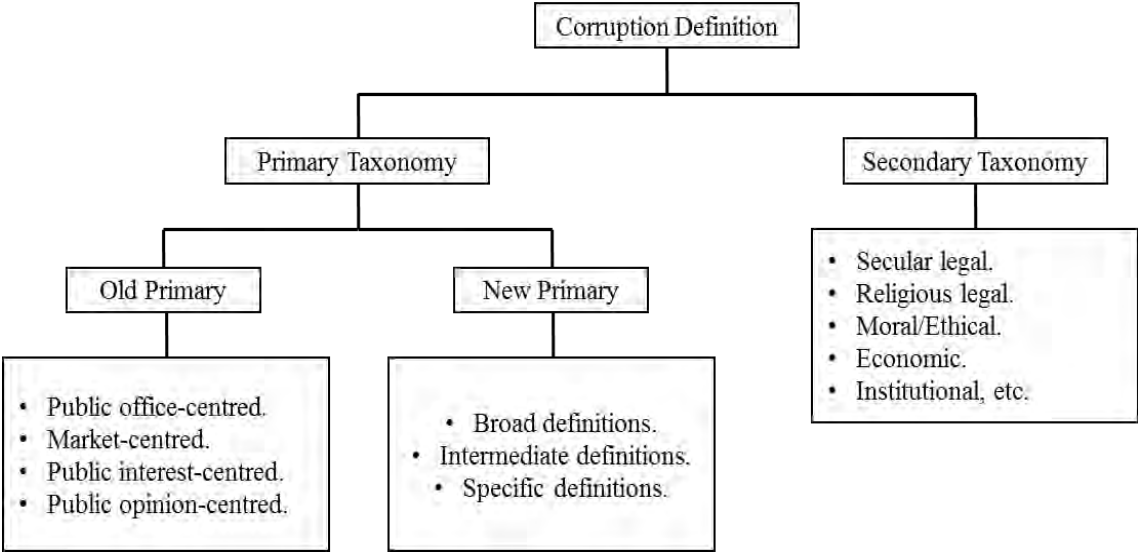
The study of corruption as a phenomenon can be a tedious endeavour (Kalinowski, 2016), not only due to its covert nature, but also because of the complex relationships of multidisciplinary and multi-dimensional aspects that comprise and revolve around said phenomenon. Corruption can be seen from a scientific perspective as a political and economic problem, or from a more ethical perspective of cultural norms, traditions, and individuals' morals depending on context (Andvig et al., 2000). Consequently, it is difficult to present a definition of corruption that could cover this range of variables, or to articulate a definition of corruption that is broad enough to be portable across different cultures. This is because an act of corruption carried out in one culture may be seen as acceptable or even admirable in another (Sandholtz & Koetzle, 2000; Chabova, 2017). One example of such practices is gift giving in a



business context. Eicher (2009) suggests that even though practices such as the exchange of gifts or favours in a business environment might seem like acts of bribery, they might be expected in certain nations as a sign of respect, appreciation or gratitude.

Some definitions focus only on the role of governmental or public sector entities in corrupt activities. These definitions suggest that corruption is the use/misuse/improper use of public office for private gains (Bardhan, 1997; Sandholtz & Koetzle, 2000; Warf, 2016). While these definitions of corruption are fit for purpose, they lack the broadness needed to comprehend corruption as a global phenomenon. The consistent use of the term Public Office narrows the definition by assuming that those who are politicians, legislators, or other government bodies carry out all corrupt actions. Eicher (2009) states that the most restrictive definition of corruption is the one confining it to the improper use of power by a government entity. An example of which would be to define corruption as the misuse of public-office for private gain (Sandholtz & Koetzle, 2000). On the other hand, The Organization of Economic Co-operation and Development (OECD) looks at corruption from two perspectives, one of criminal law, which does not define corruption but establishes the offences for an array of corrupt behaviour, and one of policy purposes, which defines corruption as the abuse of public or private office for personal gain (OECD, 2008).

Brown (2006) reviews the different definitions of corruption by categorising them into specific groupings according to the perspective from which they are defined (Figure 1). It is identified that Public office-centred definitions of corruption (abuse of public power for private gain) remains one of the most persistent, pervasive, and widespread examples of corruption across many societies, and thus attracts a lot of focus for study and analysis. While this definition has been interpreted to be broad and covers a vast array of corrupt behaviour, the reality is that it only focuses on a specific cross-section of corruption.



**Figure 1. Taxonomies of corruption definitions [from (Brown, 2006)]**

It is clear that the interpretation of corruption is based on the perception of those who are attempting to define it. Whether researchers or international organizations, the understanding of corruption will depend on the context in which it is discussed. However, Riley and Roy

(2016) state that with regards to corruption, societies will always have the potential to be involved in it, to oppose it, and to continue to debate on its core meaning. For the purpose of this paper, corruption is defined as the misuse of entrusted power for private gain. According to Brown (2006), this is considered an intermediate definition under the new primary taxonomy.

## *2.2 Corruption in Egypt*

In order to capture the reality of the Egyptian construction industry and its corruption related issues, the characteristics of the country as a whole must be reviewed. According to the 2014 UN World Economic Situation and Prospect report, the Arab Republic of Egypt falls under the category of 'Countries with Developing Economies'. Egypt —with a population of 97.6 Million in 2017 (World Bank, 2017), can be generically characterized as possessing major aspects that are commonly found in any developing country. Such aspects include a relatively low level of education, training, and technological advancement, in addition to a high rate of corruption and political unrest (Othman, 2014). The Egyptian economy has seen rapid changes throughout the past decade. However, according to the World Bank (2018), economic activity is expected to improve and imbalances are projected to narrow further as Real GDP grew by 5.3% in fiscal year 2018, and gradually to increase to 5.6% by fiscal year 2019. One event of note occurred in November 2016 when the International Monetary Fund and the Egyptian government signed a \$12 billion loan agreement with the aim of addressing macroeconomic vulnerabilities and promoting inclusive growth and job creation. Said vulnerabilities include an overvalued exchange rate, foreign exchange shortage, which severely undermined private sector activity, a severe drop in foreign exchange reserves, large fiscal deficits; and a high level of public debt (Momani, 2018). This agreement involves many features and steps that must be taken by the Egyptian government, one of which is the floatation of the Egyptian currency. This resulted in the steep decline of the Egyptian currency where on the 28th of November 2016, £1 was equals to LE10.91 as opposed to its current value of LE23.56 (HM Revenue & Customs, 2018).

Abdel Meguid et al. (2011) suggests that possessing high levels of corruption was one of the factors that triggered the 2011 uprisings. However, recent reports suggest that corruption rates in Egypt have not seen any major changes (Mourdoukoutas, 2017). This is emphasised by the comparison between Egypt's CPI ranking for 2010, and 2018. It is found that in 2010, Egypt ranked the 98<sup>th</sup> out of 175 countries. Yet, in 2018 where Egypt ranked at 105<sup>th</sup> out of 180 countries (Transparency International, 2019). GAN Integrity (2018) highlights how widespread corruption is in Egypt, warning international businesses to expect corrupt activities when dealing with the Judicial System, the Police, Land Administration, Tax Administration, Customs Administration, Public Procurement, Natural Resources, Legislation, and Civil Society.

Egypt's Penal Code criminalizes several forms of corruption such as active and passive bribery and abuse of office, but existing legislation is unevenly enforced, leading government officials to act with impunity; which is not to say that officials are immune to legal punishment (GAN Integrity, 2018). In addition, the country is yet to introduce laws to ensure comprehensive

whistleblowing frameworks across the public, private, and civil society sectors, or to ensure the protection of whistle-blowers (Transparency International, 2015).

### *2.3. The Egyptian construction industry*

Academic resources describing the mechanisms of the Egyptian construction industry are scarce. It is understood that construction is considered one of the crucial industries in Egyptian economy behind agriculture and oil with 4.8% of the country's GDP in 2015 (Dziekonski et al., 2018). In addition, it is forecast that the Egyptian construction industry will be valued \$5,355.4 million by 2021 (Marketline, 2017). Dziekonski et al. (2018) suggests that Egypt is encountering a surge in new construction developments with plans including the development of 1 million affordable housing units and the expansion of the Cairo metro. The non-residential segment is currently dominating the Egyptian construction industry, accounting for 90.1% of the total industry value. El-Gohary & Aziz (2014) suggest that the most prominent procurement route used in the Egyptian construction industry is design-bid-build, which means that operatives are mostly under the management and supervision of the contractor. El-Ehwany (2009) reports, on average, there are more than 2 million individuals working in construction, which is 9.6% of the total employment in Egypt. However, this number may not be accurate because around 86% of the workforce involved in construction work informally (El-Ehwany, 2009).

In order to execute works worth more than LE 50,000, contractors must be registered members of the Egyptian Federation for Construction & Building Contractors (EFCBC), which ranks contracting firms according to size. El-Ehwany (2009) suggests that the majority of construction firms are small in size, and perform small-scale labour-intensive activities. It is stated that there are thousands of contracting firms working informally to avoid registration fees, and taxation.

### *2.4. Corruption in the construction industry*

Construction is considered the most corrupt industry worldwide (Gunduz & Onder, 2013; Mukumbwa & Muya, 2013; Le et al., 2014). Kyriacou et al. (2015) suggests that corruption related practices in the industry amounts to an estimate of \$340 billion of global construction costs annually, which can be translated into about 10% of the industry's market value. It is also stated that corruption in the industry leads to financial issues such as cost overruns, and can affect the quality of the output. This results in deficient maintenance, and elevated operational costs. Furthermore, evidence is presented suggesting that many construction-related catastrophes have been linked to one form of corruption or another. In addition, corrupt practices taking place in public construction projects can have major negative effects on countries with developing economies. Le et al. (2014) presents the impacts of corruption on the construction industry by dividing the different repercussions of corrupt actions on the industry under three distinct groups that represent the various levels affected; micro (project) level, moderate (industry) level, and macro (global level).

Le et al. (2014) suggests that corrupt actions are partly associated with the fragmented nature of the industry. In addition, several other possible corruption causes in the construction industry are presented (Table 1).

Table 1. Corruption causes in the construction industry (source: Le et al. (2014))

Source	Corruption Cause
(Zarkada-Fraser and Skitmore, 2000; Liu et al., 2004; Moodley et al. 2008)	Corruption because of unethical decisions.
(Bologna and Del Nord 2000)	Corruption worsened by insufficient legal punishments and penalties.
(Bowen et al, 2012)	Lack of positive role models of public figures.
(Tabish and Jha, 2011)	Lack of standardized execution in construction projects.
(Sohail and Cavill, 2008)	Over-competition in the tendering process. Insufficient transparency in the selection criteria for tenderers. Inappropriate political interference in cost decisions. Complexity of institutional roles and functions. Asymmetric information amongst project parties

Construction corruption is a global issue that does not discriminate according to certain countries' economic standing. This is evident from sources such as Gunduz & Onder (2013), which discusses fraud in the Turkish construction market; Bowen et al. (2015), which discusses construction corruption from the clients' point of view in South Africa; Brown & Loosemore (2015), which discuss construction corruption in the Australian market; Mukumbwa & Muya (2013), which focuses on ethics in the Zambian construction industry.

## 2.5. Conclusions

After reviewing the literature, it is clear that the study of corruption in the context of the construction industry is of vital importance. The involvement of many fragmented parties to achieve a single high capital endeavour (among other aspects) makes the industry susceptible to corrupt activities. Therefore, it is not surprising that construction has been named one of the most corrupt industries worldwide. In addition, the scale by which corruption impacts projects,

the industry, and even entire economies is staggering enough to motivate researchers, governments, and NGO's to find strategies against this imminent threat.

For a country such as Egypt where the construction industry plays a vital role in the mechanisms of its economy, the focus on corruption in construction becomes imperative. The Egyptian construction industry has seen a lot of challenges and changes in the past. The core of these challenges seemed to have revolved around the economic and political climate in the country. It is evident that Egypt suffers from high levels of corruption, which caused at least in part the uprisings of January 2011. However, almost a decade later, it is clear that corruption issues in Egypt are not being rectified. Therefore, if the construction industry is one of the most corrupt industries worldwide, and corruption levels are high in Egypt, it can be hypothesised that the Egyptian construction industry suffers from high levels of corruption. Due to the lack of resources regarding this specific issue, primary data collection must be undertaken to provide accurate narrative that represents the state of corruption in the context of the Egyptian construction industry including its underlying causes, its forms, and its impacts. The following section provides a detailed account of the methods used for data collection.

### 3. Research Methods

#### 3.1. Data Collection

Semi-structured interviews were used to collect the required data because they allow expansive and tangential discussions that delve deeper into the participants' experience. From the literature review, 6 main areas were identified to be discussed during the interviews (Table 2). Guide questions were created to explore each individual area. In total, 38 questions were created to guide the interview process. The first 4 questions were created to develop rapport with the participants such as their years of experience in their current position, and their experience in the industry in general. Special attention was paid to make sure there was no identifiable information collected from the participants.

Table 2. Data collection areas

No.	Item
1	Corruption in Egypt
2	Corruption in the Egyptian construction industry.
3	Corruption forms and projects' lifecycles.
4	Corruption and project size/types.
5	Causes and impacts of corruption
6	The attitude of construction companies towards corruption.

## Sampling

In order to provide a comprehensive picture of Egyptian construction corruption, it was essential for the sample selected for this fieldwork to cover a wide variety of backgrounds within the industry. In addition, it was important to cover both private and public sectors, and to interview individuals who operate at different levels of the hierarchy: strategic, tactical, and operational. Furthermore, the sample covered individuals who represent all parties involved in the construction process such as individuals who work in contracting firms, engineering consultants, and client organisations/real estate developers.

A Snowball sampling technique was adopted to allocate participants. This involved making initial contact with known and willing individuals, followed by others whom the initial contacts nominate for participation. Due to the sensitivity of the topic, this chain referral method was the best method to recruit participants who are willing to discuss the research topic. In order to avoid identification of later participants, initial participants were asked to nominate multiple individuals, and were not informed whether their nominations were contacted or not; which was a close variation of the exponential discriminative snowball sampling technique.

During initial contact with potential participants, a summary comprised of the aim and objectives of the research was provided via telephone. Upon agreement to participate, participants were provided with a detailed verbal brief of about 30 minutes, during which further details regarding the research were communicated. In addition, participants were informed about how their identities will be kept anonymous, how the interview recordings will be handled, and how the data will be analysed. Furthermore, participants were informed that they are allowed to change their minds regarding their participation at any point in time leading to the final submission of this research.

The total number of interviews carried out for this data collection process is 18. The duration of the interviews ranged from 40 to 90 minutes, in addition to the 30 minutes initial brief. They were carried out in the offices of each individual participant. No record of the participants' names, job titles, or affiliated companies has been kept due to privacy concerns. Table 3 provides general descriptions of the participants based on their level, party, and sector. For example, Case PR-CL-ST-01 was an individual working for a private sector client organisation –real-estate developer whose role in the company was strategic in nature.

Table 3. Criteria of Data Collection Sample

Interviewee Code	Sector	Party	Level
Cases\\PR-CL-ST-01	Private	Client Organisation	Strategic
Cases\\PR-CL-ST-02	Private	Client Organisation	Strategic
Cases\\PR-CL-ST-03	Private	Client Organisation	Strategic
Cases\\PR-CO-CN-01	Private	Contracting Firm	Contracts
Cases\\PR-CO-OP-01	Private	Contracting Firm	Operative

Cases\\PR-CO-OP-02	Private	Contracting Firm	Operative
Cases\\PR-CO-OP-03	Private	Contracting Firm	Operative
Cases\\PR-CO-ST-01	Private	Contracting Firm	Strategic
Cases\\PR-CO-ST-02	Private	Contracting Firm	Strategic
Cases\\PR-CO-ST-03	Private	Contracting Firm	Strategic
Cases\\PR-CO-TA-01	Private	Contracting Firm	Tactical
Cases\\PR-CO-TA-02	Private	Contracting Firm	Tactical
Cases\\PR-DS-TA-01	Private	Design Firm	Tactical
Cases\\PR-EN-ST-01	Private	Engineering Consultants	Strategic
Cases\\PR-EN-TA-01	Private	Engineering Consultants	Tactical
Cases\\PU-CL-TA-01	Public	Client Organisation	Tactical
Cases\\PU-CL-TA-02	Public	Client Organisation	Tactical
Cases\\PU-CL-TA-03	Public	Client Organisation	Tactical

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### *Data Management & Analysis*

Since the data collection process took place in Cairo, Egypt, all interviews were carried out in Arabic. Due to the sensitivity of the research's subject matter, it was highly important to keep participants' identity safe. The focus of this paper is on the construction industry, but when studying corruption, the topic expands itself to cover issues such as politics, economics, and social issues. All these topics are intertwined with corruption regardless of what context it is being studied in. The interviews were recorded on a professional audio recorder, and then transferred to an encrypted hard-drive. The hard-drive was then securely transported from Cairo to Heriot-Watt University where the audio files were transferred to a secure computer. All translations, transcriptions, and analysis were carried out on this computer. NVivo 11 was used as a tool to organise the data, and aid in its interpretation. Thematic analysis was carried out to provide comprehensive information related to the issues raised in Table 2. Following the completion of the project, all digital files collected or created for this data collection process will be destroyed with the aid of the university's IT department, and any printouts or physical document will be appropriately shredded.

### **4. Findings from Data Analysis**

By processing the interview transcripts using thematic analysis, two groups of themes were elicited from the data: one group directly related to the scope of this research, and another group provided secondary themes, which were deemed of interest. The first group of themes related to the research areas illustrated in Table 2, which were 'Corruption in Egypt', 'Corruption in the Egyptian Construction Industry', 'Corruption Forms and Projects' Lifecycles', 'Corruption and Project Size/Type', 'Corruption Causes and Impacts', and 'The Attitude of Construction

Companies Towards Corruption'. Themes that comprised the secondary group were 'Defining Corruption', 'Corruption Confusion', 'Rationalising Corruption', 'Resistance to Change', and 'Freedom of Speech'. This paper will present and discuss themes from the first group.

#### *4.1. Corruption in Egypt*

This theme provides an understanding of Egypt's situation in relation to corruption based on participants' experiences and perceptions. All participants agreed that Egypt possesses high levels of corruption. Within this theme, 3 subthemes were identified, 'Corruption Normalcy', 'Bureaucratic Systems', and 'Anticorruption Entities'.

Regarding Corruption Normalcy, PR-CL-ST-02 said "In Egypt, it [corruption] became part of the culture. It has become the norm", while PU-CL-TA-03 stated "I can tell you that it [corruption] is part of the culture now; people twist their actions in order not to feel guilty. Then, they forget that they have twisted their actions, and it just becomes normal. This is life in Egypt". The repetition of terms such as "part of the culture" and "is the norm" in relation to corruption levels in Egypt was seen across the transcripts.

The mention of Egypt's bureaucratic systems was also seen throughout the transcripts in a negative light. Participants connected this to high corruption levels. PR-EN-TA-01 said "It [corruption] is very common, especially in any governmental institution or establishment", and PU-CL-TA-01 stated "The power of a public servant is a stamp or a signature, which is all they possess. They will use that power to extort money out of people".

Participants viewed existing anti-corruption establishments as ineffective. PR-CL-ST-03 said "It is not efficient. The laws are there but it is not efficient. It is more political", and with regards to reporting corrupt actions to authority, PR-CO-OP-01 stated "They may come forward and report, but what is going to happen afterward, nothing whatsoever".

The data confirms corruption is widespread in Egypt. In addition, corrupt actions are part of the day-to-day life of Egyptian citizens, especially when interacting with public servants. However, these actions are not limited to bureaucratic interactions but are experienced in all aspects of society. The data identified three factors influencing corruption levels in Egypt: corruption normalcy, inefficient bureaucratic systems, and inefficient anti-corruption entities. These factors have a directly proportionate relationship with corruption levels, and with each other.

In Egypt, corruption is part of doing business. However, those who participate in such actions often refrain from referring to them as corrupt. Certain individuals do not view these actions as corrupt at all, while others acknowledge their illicit nature yet participate anyway due to social or financial pressures. There exists a degree of misunderstanding regarding corruption. The term is perceived as an issue relating to those who possess high levels of political and financial powers. In addition, there is a separation between criminality and illicitness. Grand corruption forms involving large sums of money or influence are perceived as corrupt due to their obvious criminality. On the other hand, petty corruption forms such as facilitation payments are mostly overlooked due to their scale. The normalcy of corrupt actions



within the Egyptian culture increases corruption levels. In addition, the rise of such normalcy results in more inefficient bureaucratic systems, and anti-corruption entities.

The prevalent example representing corruption in Egypt lies within its bureaucratic systems. The interactions between individuals and public servants are infested with corrupt actions. This paper defines corruption as the misuse of entrusted power for private gain. The ‘gain’ aspect of these corrupt actions may not be illicit in itself. An individual is within their right to request a certain document from a bureaucratic entity. However, since this entity is not efficient and thus slow, said individual may resort to facilitation payments to receive their requested document. The public servants themselves may also instigate this process. The inefficiency of Egypt’s bureaucratic increases corruption rates. In addition, these systems result in inefficient anti-corruption entities, and increases corruption normalcy.

The data suggests that while there are laws and regulations that cover a range of corrupt actions, their enforcement is not optimal. The entities responsible for monitoring and controlling corrupt actions are not efficient. This relates to the previous point because these entities operate as a bureaucratic system. In addition, the rate by which these anti-corruption entities enforce the law and regulations is subjective. Corrupt actions may be discovered through monitoring, or directly reported to these entities but the decision to enforce the law will rely heavily on political influence. The inefficiency of existing anti-corruption entities increases corruption rates. In addition, it allows for inefficient bureaucratic systems, and increases corruption normalcy.

#### *4.2. Corruption in the Egyptian construction industry*

This theme was comprised of two connected subthemes. ‘The Level of Corruption in the Egyptian Construction Industry’, which identified the rate of corruption in the industry, and ‘Country and Industry’, which explored the connection between the construction industry and the country. Participants expressed that corruption levels in the industry are high. PR-EN-TA-01 said “Yes, corruption is very common in the industry; especially with local companies”, and PR-CO-ST-01 stated “I can spend days telling you about all the corrupt things that happen in that industry”. In addition, participants expressed that the industry is a representation of the country.

It is vital to recognise that the construction industry does not exist in a void; the country and the industry possess a direct relationship. The data suggests that the magnitude of corruption perceived and experienced in the construction industry is identical to the one relating to the country. This means that the Egyptian construction industry suffers from elevated rates of corruption. Similarly, corruption is considered a part of the industry’s culture. It is understood within the Egyptian construction market that each party involved in a project is continuously attempting to take advantage of the others. The prevailing attitude that exists within the industry is one of trickery.

#### *4.3. Corruption forms and projects’ lifecycles*

This theme identifies the various corruption forms that occur along the lifecycle of construction projects, and attempts to detect which project stage is most susceptible to

corruption. This theme is comprised of three subthemes, ‘Corrupt Actions’, which identifies corruption forms along different project stages, and ‘Corruption in the Project Lifecycle’, which examines which project stage is the most corrupt. Finally, the ‘Most Prominent Corruption Form’, which sought to identify the most recurring corruption form. Corruption forms identified by the participants are bribery, fraud, collusion, conflict of interest, extortion, bid-rigging, negligence, embezzlement, and favouritism and nepotism.

Participants expressed that corrupt actions appear in different forms at different stages of the project. PR-CL-ST-01 said “It occurs along the lifecycle of the project. Each stage has its own challenges, and each stage allows for corrupt activities to take place”, and PR-CO-OP-03 “The whole project is riddled with corruption”.

Corruption occurs along the lifecycle of a typical construction project. However, it is difficult to identify which particular stage possesses higher levels of corruption, or which is more susceptible to corruption. Each participant viewed the areas they are most involved in to be the most corrupt and the most susceptible to corruption. Each stage possesses its own vulnerabilities that allow certain corruption forms to occur. For example, participants suggested that the tendering stage is the most susceptible to corruption because corrupt actions at this stage will affect all the following stages. Alternatively, other participants stated that the construction stage is more susceptible to corruption because it involves more individuals, and typically possesses a longer timeframe. The process of judging which stage is more corrupt will depend on how corruption is measured. Table 4 illustrates the corruption forms that occur at each project stage.

Table 4. Corrupt actions along project lifecycle

Project stage	Corrupt Actions
Planning	Fraud, Collusion, and Conflict of interest.
Tendering	Bribery, conflict of interest, collusion, favouritism and nepotism, and bid rigging.
Purchasing	Bribery, conflict of interest, collusion, favouritism and nepotism, negligence, and fraud.
Construction	Bribery, conflict of interest, collusion, favouritism and nepotism, negligence, and extortion.
Handing over	Bribery and negligence.
Operation & Maintenance	Bribery, conflict of interest, collusion, favouritism and nepotism, and embezzlement.

In addition, participants expressed difficulty identifying one prominent form, instead, PR-EN-ST-01 said “It is the people, really. There is no one type that is more widespread than the others but people are the common factor”, and PR-EN-TA-01 stated “I do not think that there is one form of corruption that occurs more than the others, I think all these forms operate hand in hand; they all work together. It is all about easy money, through any means necessary”.

The most prominent corruption form in the Egyptian construction industry could not be identified from the collected data. There was no consensus regarding a specific corruption form. This leads to the conclusion that the occurrence of each corrupt action depends on the individuals who carry out this action, and the situation surrounding it.

#### *4.4 Corruption and project size/type*

This theme investigates the relationship between the rate of corrupt actions, and the size of a construction project. In addition, it identifies project types that are most susceptible to corruption. This theme is comprised of two subthemes, ‘Corruption in Relation to Project Size’, which explores the connection between corruption rates and project size, and ‘Corrupt Projects’, which identifies the most corrupt project types. Participants provided conflicting opinions regarding the relationship between corruption rates and project size. For example, PR-CO-ST-01 expressed “The larger the project, the more corruption you will find”. Conversely, PR-CL-ST-01 suggested that “I believe it is an inversely proportionate relationship. The larger the project, the less corruption you will see”.

The relationship between project size and the rate of corruption is considered subjective. This is due to the many variables involved in the process. Participants suggested three opinions relating to this matter:

- 1) Larger projects possess lower levels of corruption due to the assumption that they often have better and more efficient control systems.
- 2) Larger projects are likely to possess higher levels of corruption due to the involvement of more individuals and larger sums of money within these projects.
- 3) There is no correlation between project size and corruption rates.

While the first two opinions may be valid in some cases, the data does not suggest that a generalisation can be made to support either one. This leads to the conclusion that there is no correlation between project size, and the rate of corruption. Instead, corruption rates depend on the individuals rather than the scale of the project.

Participants expressed that construction projects that involve repetitive actions, vast groundworks, and connections to the public sector are the most corrupt. In addition, they are the most susceptible to corruption. PR-CL-ST-02 said “Public sector projects are the most corrupt, any type of project within that”, while PR-CL-ST-03 mentioned “Any project where the elements are hidden, really. Because it is hard to catch what you cannot see. Hidden and repetitive works”. One agreed upon aspect is that public sector projects are the most susceptible to corruption. It is concluded that roadworks, groundworks, and infrastructure projects are considered the most corrupt.

#### *4.5 Corruption causes and impacts*

This theme identifies the underlying causes of corruption, and the impact of corruption in the Egyptian construction industry. The subthemes involved were labelled ‘Corruption Causes’, and ‘Corruption Impacts’.

#### 4.6. Corruption causes

Participants expressed that the underlying causes of corruption are need, greed, and lack of ownership. PR-CO-OP-02 said “Some people’s salaries are so low that they get tempted to take the corrupt route, and other people just want more money and they will get it in any way possible”, and PR-EN-ST-01 stated “Most people who act like this do it out of greed, some out of need, but overall I think it’s because they don’t feel connected to their job. There’s no passion or self-fulfilment, so they just try to get away with whatever they can”.

Through analysing participants’ comments regarding these three causes, the following was concluded:

- **Need:** Individuals may seek acting in an illicit manner due to a failure in providing financial support for their dependants. This is highlighted by the uneven distribution of wealth, and the lower minimum wages that exist in Egypt. The need to provide may force individuals to gain financial or social outcomes through corrupt actions.
- **Greed:** Individuals may seek acting in an illicit manner regardless of their financial or social standing. This means that individuals will seek corrupt actions to generate wealth purely based on the urge of enhancing their possessions.
- **Lack of ownership:** Individuals may seek acting in an illicit manner due to a lack in their sense of ownership relating to the position where they operate. This can be related to a certain task, project, or company. The data suggests that there is a separation between individuals and their professional environment, which may result in aspirations of private gains through illicit means.

#### 4.7. Corruption impacts

Participants stated that corruption impacts projects’ time, cost, and quality. In addition, it creates a mistrustful business environment. PR-CL-ST-02 said “It damages the quality of work, and it results in a lot of reworks which leads to more money and more time”.

Corrupt actions that occur in the Egyptian construction industry are presented in Table 4. These actions negatively affect the industry. The data suggests that the presence of these actions results in a negative perception of the local construction market by the general public. It is also mentioned that acting in a corrupt manner is key to surviving in the Egyptian construction market. This means that a party that does not want to be involved in corrupt actions will not be able to compete in the construction market. This results in an unfair business environment. The aforementioned corrupt actions also lead to a level of mistrust within and towards the Egyptian construction industry. These corrupt actions automatically result in a rise in corruption levels in the industry, and thus elevate corruption rates in the country. This causes a feedback which enables corruption normalcy. In addition, the quality of materials and construction outputs are negatively affected. Furthermore, projects tend to be over-budget, and deadlines become difficult to meet. The result becomes poor quality projects that are cost overrun, and late in completion. From this information, it is concluded that corruption impacts are categorised into three levels: the project level, the industry level, and the country level. Table 5 relates these levels to the identified corruption impacts.

Table 5. Corruption impacts at different levels

Level	Corruption Impacts
	Long project duration.
Project Level	Increased project costs. Poor quality end products. Poor reputation.
Industry Level	Lack of trust. Unfair business environment.
Country Level	Elevated corruption rates. Increased corruption normalcy.

#### 4.8. Construction companies and corruption

This theme explores the attitudes of construction companies in Egypt toward corruption. This theme is comprised of two subthemes, ‘Companies and Corruption’, and ‘Survival without Corruption’. The first revealed that construction companies in Egypt do not seek to minimise corruption in general. In addition, these companies only react to corrupt actions that would damage them, while ignoring or even celebrating actions that provide benefit. PR-CL-ST-01 said “If someone is stealing from the company, they will be punished. If someone is stealing for the company, then they will most probably be rewarded”, and PR-CO-OP-03 stated “They only care when they lose, but if they are making money off of an employee’s corruption, they will celebrate that individual”.

Participants highlighted that it is almost impossible to survive in the Egyptian corruption industry without being involved in at least a minor form of corruption. PR-CO-TA-01 confirmed this by saying “If you are involved in the construction industry in Egypt, you have to take part in at least a small amount of corruption”.

Egyptian construction companies do not possess regulatory systems that actively manage corruption. The data suggests that if such internal regulations exist, they only focus on protecting the companies from actions which could directly victimize them. These actions often involve large sums of money, and individuals in powerful positions. It must be understood that these companies operate in an already corrupt environment. Therefore, corrupt actions which benefit a company are often welcomed, while corrupt actions that damage a company are punished.

On the other hand, corrupt actions that occur on a smaller scale receive no focus whatsoever. These actions occur on a day-to-day basis, and are seen as part of the operation methods. There are no monitoring structures targeting these actions. Instead, the main reliance is on individuals’ morals. The assumption is that employees know right from wrong. Thus,

corruption related issues are not communicated to employees. There are no training programmes, or corruption awareness campaigns provided for individuals who operate in the Egyptian construction industry.

## 5. Conclusions

This paper set out to provide a narrative illustrating the state of the Egyptian construction industry in relation to corruption. By reviewing the literature, six research areas were identified. Semi-structured interviews were carried out to provide further understanding regarding the identified research areas. Through thematic analysis, it was determined that corruption is a prominent aspect of the construction industry in Egypt. Varying corruption forms were identified in both public and private sectors, and within all construction project stages. However, public sector projects involving roadworks, groundworks, and infrastructure were viewed as the most corrupt. The data did not provide any evidence to support a correlation between project size and corruption rates. The underlying causes of corrupt actions were identified as need, greed, and a lack in the sense of ownership within the construction industry workforce. It was concluded that the impacts of corrupt actions were experienced at three levels; the project level, the industry level, and the country level. At the project level, corrupt actions result in projects that are over-budget, over-time, and of a poorer quality. At the industry level, corrupt actions transformed the industry into an unfair environment possessing a negative reputation and high levels of mistrust. At the country level, the increase in corrupt actions resulted in elevated corruption levels for the country as a whole, and reinforced the normalcy of corrupt behaviour. Despite of the aforementioned impacts, it was evident that construction companies have not identified corruption as a major issue within the industry. Instead, corruption was normalised, and seen as another aspect of doing business.

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## Appendix: Semi-structured Interviews Guide Questions

### 1. Introductions – Corruption in Egypt

- How long have you been in your current position?
- How long have you been involved in the construction industry?
- Was your involvement in the industry all in Egypt?
- What about your education, did it take place in Egypt?
- Can you tell me what the word “Corruption” means to you?
- What about “The misuse of entrusted power for private gain”, is that a fitting definition of corruption?
- Knowing this, do you think things like Bakshish (bribes) and Wasta (favouritism/nepotism), for example, fit this definition?
- What other activities that you are aware of fit this definition of corruption (that occur in Egypt)?
- What about [give any missing forms of corruption]?
- In your experience, do you think such activities are normal in day to day Egyptian life?

### 2. Corruption in the Egyptian Construction Industry

- Taking the aforementioned definition of corruption and applying it to the construction industry: Do you think there are activities in the industry that fit such definition?
- In your experience, and with reference to the corruption definition used for this research, how common would you say such activities occur in the Egyptian construction industry.

### 3. Corruption Forms and the project lifecycle

- From your experience in the industry, may you provide me with examples of such activities occurring in the industry as a whole i.e. private and public sector?
- What about activities such as [give any missing forms of corruption]?
- When do you think these activities occur along a project’s lifecycle.
- [Run through each corrupt activity]
- In your opinion, which stage in the project lifecycle is the most vulnerable?

### 4. Corruption and Project Size/Type

- Do you believe there is a correlation between project size and corruption rates?
- What types of projects have you been involved in?
- Are all these private sector projects, or have been you involved with the public sector in any of them?
- In the projects you have been involved in, did you experience any of the aforementioned forms of corruption?
- What type of project did you witness the most corrupt activities in?

### 5. Corruption Causes and Impacts

- In general, what do you think motivates people to be involved in corrupt activities?
- Regarding the aforementioned projects, do you think said corrupt activities occur because of the culture of corruption in Egypt, because of the nature of the industry, or both?
- [Discuss this point further according to reply]

- Out of all the corruption forms we discussed, which form is most likely to occur in the Egyptian construction industry?
  - Are you able to tell me why that corruption form specifically?
  - Have you ever witnessed that corruption form yourself?
  - [If not] In your experience, has any of your colleagues (in this company or others) experienced said form?
  - In what way do you think this corruption form affects a project?
  - How do corrupt actions affect construction companies and/or the industry itself?
6. The attitude of construction companies towards corruption
- Does the general attitude of the industry towards corruption match the country's attitude?
  - Hypothetically speaking, if an individual who operates in a construction company is involved in corrupt activities, but these corrupt activities are beneficial to the company; how will said company deal with this individual?
  - How will a company deal with an individual who is involved in corrupt activities within the company itself in comparison to corrupt activities targeted at a third party? Whether beneficial or not.
  - Do construction companies in Egypt have any form of internal rules that govern corrupt activities?
  - Do construction companies in Egypt communicate or train their employees regarding corruption related issues.
  - Is there a system in place within construction companies that allow for secure whistleblowing?

What about the country as a whole, is there a system in place to allow for secure

# Work Group Characteristics as Determinant of Project Team Effectiveness in Construction

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## Abstract:

Construction industry is characterized by project-based production, both in the design as well as in the building construction segment. As a consequence, this capital-intensive industry is highly dependant on people, more specifically on work groups' effectiveness. Generally, many scholars investigated characteristics of teams and team members in relation to work group effectiveness. However, it is widely appreciated that these issues are field specific and more over that they change over time. Since there have been no recent studies regarding work group effectiveness in construction industry in Croatia, this paper aims to fill that knowledge gap. After providing an insight into relevant literature review, results of a case study conducted in small and medium size construction companies shall be presented. Results refer to relation between work group characteristics and effectiveness. As such, they provide guidance to both managerial decisions and future academic researchers.

*Keywords: project team; performance; work group characteristics*

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## 1. Introduction

The use of teams has expanded dramatically in response to competitive challenges and organizational needs of flexibility and adaptation (Pina et al., 2008). In some business segments such a trend is even more obvious due to the disposition of activities performed. For instance, the use of teams in the engineering world has become commonplace (Doolen et al. 2006).

Construction is dominated by project-based production (Vrijhoef, Koskela, 2005). But, due to prevalence of the “one of a kind” product mix which results from the industry’s project nature, there are often the complaints about the state of practice (Turin, 2003). The background of such performance irregularity rises from the fact that determinants of project success are not always straightforward and unambiguous (Phua, 2004). This significant managerial challenge has inspired the study presented in this paper – to learn and understand the major determinants of project team effectiveness in construction industry.

Despite the value of the machinery and equipment, construction industry is a labor-intensive business, especially its designing segment. That's why it has been said that the capability of handling the culture-issue within construction processes is a kind of risk-management tool, because using it reduces the risk of behavioral miscommunication (Tijhuis, 2012).

Behavior is significantly determined by organizational culture, i.e. by the basic values and assumptions shared by members of a group. As such, organizational culture is the group’s view

of itself and its environment as well as its way of performing daily activities. In terms of organizational culture, the group can stand for a nation, an industry segment, a company, a team or any other relatively stable social construct.

However, this raises additional question: are behavior related issues like project team effectiveness not only subject but also site specific? The fact is that differences and concurrent interconnection between organizational (corporate) culture and national culture should be considered: national cultures differ mainly on the level of fundamental values, while organizational cultures alter more on the level of perfunctory practices and can be more manageable. In a bottom line, organizational culture is determined by the national culture (Hofstede, 1998).

Professor Hofstede and his team have conducted the most comprehensive research regarding particularities of organizational (national) culture in 64 different countries. They have described the nature of cultural characteristics within each country by attributing scores (ranging from 0-100) for six different cultural dimensions (Hofstede et al., 2010).

Additionally, previous findings (Chan, Tse, 2003; Overbaugh, 2013) suggested that culture dimensions affect economic and business performance at the country level differently, so nation-specific studies of work group effectiveness are welcome. Building on such conclusions, this paper presents the case of Croatian construction design segment.

Recent study conducted in Croatia (Šandrak Nukić, Načinović Braje, 2017) revealed that two of those dimensions are statistically significant predictors of Croatia's competitiveness: uncertainty avoidance with a negative sign and long term versus short term orientation with a positive association.

Uncertainty avoidance dimension expresses the degree to which the members of a society feel uncomfortable with uncertainty, especially the fact that the future is unknown and insecure. Index scores higher than 50 expose high uncertainty avoidance, which involves avoiding risks and any changes. Croatia scores 80 in this dimension, meaning that its population is mostly intolerant of unconventional behavior and innovative ideas, in order to avoid risks.

Long versus short term orientation describes society's attitude towards past, present and future. Long-term orientation countries are detected after dimension scores above 50 and Croatia's is 58. As a result, Croatian's value thrift and efforts in modern education as a way to prepare for the future.

In the case of Croatia, high uncertainty avoidance score undermines the national competitiveness level. Yet, the increase of long-term orientation improves national competitiveness. As the relation among organizational culture, competitiveness, effectiveness and efficiency is straightforward (Gómez-Miranda et al. 2015) these findings are relevant.

Leaning on Hofstede's culture dimensions, there have been several scholars studying and constructing typologies of organizational culture. Out of those, Cameron and Quinn's (2005) typology has been used for identification of culture types in Croatia's construction industry (Šandrak Nukić, 2018). The research proved that, although the Croatian construction industry's culture type is primarily hierarchy, there are certain differences among the main stakeholders.

More specifically, designers' function as predominantly clan type organizational cultures. This means that such companies are usually friendly place to work in, which are held together by loyalty and collaboration. Construction design companies in Croatia are mostly family-type organizations in terms that superiors are considered mentors and peers are considered extended family members. Such companies are characterized by high commitment to employees, and above all – participation and teamwork.

Building on the above presented body of knowledge, the study presented in this paper argues that project team effectiveness should appreciate national differences and therefore examines the Croatian case of small and medium size construction design companies.

## **2. Theoretical framework**

Because of the central role of projects in construction, project managers have an important role. The project manager has the responsibility for the design as well as the execution, matches the project and the customer needs, and takes care of the entire production management. Achieving team effectiveness is an ultimate goal so it is crucial to identify and control factors in behind of it.

Discourse on factors determining effectiveness is primarily a discourse on competencies. Competencies are individual characteristics, including knowledge, skills, abilities and other characteristics (self-image, traits, mindsets, feelings, ways of thinking), which, when used with the appropriate roles, achieve a desired result. Competencies contribute to individual exemplary performance that creates reasonable impact on business outcomes (SHRM, 2012; Campion et al., 2011). In addition, although individual competencies are important, it should be emphasized that, when analyzing engineering projects, competencies need to be seen in the context of what a team is required to perform well (Margerison, 2001).

Competency modelling has become indispensable in human resources management since it is being used for many purposes (Campion et al. 2011):

- hire new employees by using assessment and other selection procedures,
- train employees by creating courses aimed at the development of certain competences,
- evaluate the performance of employees,
- promote employees by using the competencies to establish promotion criteria,
- develop employee careers by using the competency models to guide the choice of job assignments and make other career choices,
- manage employee information by using the competency model to record and archive employee skill, training, and job experience information,
- compensate employees and structure pay differences,
- manage retention of critical skills,
- support organizational change.

Having in mind the purpose of this paper, authors focused primarily on using competency model for performance evaluation. But even narrowing the research to team performance

(effectiveness) models, literature review leads to several different approaches (Gladstein, 1984; Hackman 1987; Hall and Beyerlein, 2000; Sundstrom et al. 1990).

Generally, the models can be grouped into two main groups (Pina et al., 2008). Models in the first group are one-dimensional, so they test only objective measures of team performance, being defined through performance/productivity. The second group includes multidimensional models whose starting assumption is that teams are complex so their effectiveness must include several variables, not only productivity.

Since engineering projects always ask for sound technical, quantitative and analytical individual achievements while at the same time encourage team level-behaviours such as collaboration and communication (Doolen et al. 2006), authors suggest analyzing team effectiveness in construction industry by using the multidimensional approach.

Among the multidimensional models, academic literature recognizes different effectiveness determinants.

In some studies (Pina et al., 2008), determinants are categorized and tested as objective and subjective. Objective determinants are related to performance and include:

- adherence to budgets,
- adherence to time schedules,
- innovation,
- project quality,
- overall company performance (sales growth, return on equity or change in profitability),
- outcomes of interactions among team members.

Objective measures are specific to the task and the type of team while subjective measures are gathered through survey questions focused on perceptions of team members themselves (internal perceptions) and managers or other stakeholders like customers and investors (external perceptions).

Regarding subjective determinants, attitudinal outcomes like satisfaction, commitment and trust in management are usually noted as relevant (Baldwin et al., 1997).

Perhaps the most comprehensive study on objective and subjective determinants of work group effectiveness has been done by Campion et al., (1993), testing 80 work groups. They grouped tested determinants (characteristics) into 5 categories and defined effectiveness through 3 variables, as presented in Figure 1.

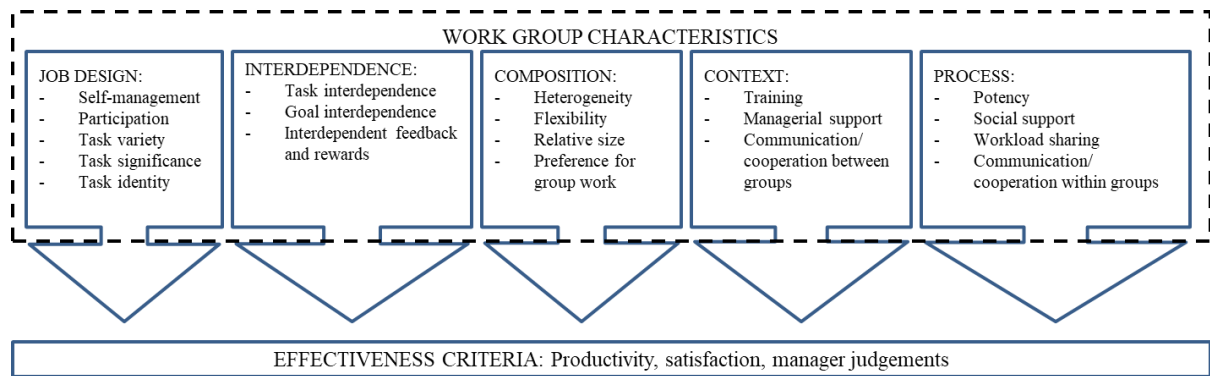


Figure 2. Work group characteristics (source: authors after Campion, A., Medsker, G., Higgs, C. (1993) Relations between work group characteristics and effectiveness: implications for designing effective work groups, Personnel Psychology 46)

The results of the study summarized in Figure 1 concluded that job design and process variables are slightly more predictive than the others.

Beside studies on subjective and objective determinants there are also studies advocating for organizational context. The organizational context that surrounds a team has been identified by researchers (Guzzo and Shea, 1992) as an important consideration in the study of team effectiveness so those researchers strongly advise to broaden team research in order to look beyond the processes between team members and to include the relationships between teams and the organization as well. They articulate that improvements in group effectiveness can be obtained by changing the circumstances in which groups work.

Considering such a perspective, it should be commented that among significant characteristics listed in Figure 1 there are indeed objective, subjective and organizational context variables, additionally supporting the completeness of Campion and his co-authors' study.

More pragmatic approach including all three types of variables but only in their essence was offered by Doolen, Hacker and Aken (2006). In their study, organizational context variables being team processes, team composition and team task have been set as independent variables. Dependent variables were both subjective (team member satisfaction) and objective team effectiveness determinants (team performance). Their results validated the importance of organizational context and proved that team processes can serve a mediating role between organizational variables and team member satisfaction.

### 3. Methodology and methods used

In the majority of the cases, team studies use survey as the instrument to gather data (Pina et al., 2008). The first issue that needs to consider when constructing a survey is the level of investigation and the other is its content.

Different approaches to level of the analysis have been used for measuring team attributes. The first type is the surveys measuring team-level data based on assessing individual team members' perceptions and then aggregating the responses to the team level. Such research methods have been criticized because aggregating items that assess individual perceptions of

confidence in one's own ability may not necessarily capture the team's collective sense of its ability to successfully accomplish team task (Tesluk et al., 1997).

In the second type of surveys, questions are written to capture not individual attributes but attributes of the team as a whole. However, still individual members are being questioned so the quality of the research significantly depends on the response rate – the greater the response rate, the more reliable the survey results (Early, 1999).

And finally, due to the problems with answers aggregation, the consensus method for gathering team-level data has been proposed (Early, 1999). It implies having all the team members together and jointly responds to survey items using consensus decision making. From the researcher point of view, this type of surveys is quite labour intensive.

Kirkman et al (2001) compared all three survey types and concluded that consensus method might, but not as a rule, be superior to others. Therefore, they recommended any of the types as adequately informative. Building on that conclusion, study presented in this paper used individual perceptions aggregated to the team level conclusions.

Regarding the content of the survey, the research presented in this paper belongs to the multidimensional approach, covering both objective and subjective determinants of team effectiveness as well as taking the organizational context into account.

In terms of quality management in construction, the attitude tends to be oriented towards conformance to contractual specifications, primarily getting the work done on time and within budget (Vrijhoef, Koskela, 2005). Therefore, out of many different team effectiveness determinants presented in theoretical part of this paper, authors have chosen being on time and within the budget as objective performance determinants. As for the subjective determinants and organizational context variables, those presented in Doolen et al (2006) have been chosen as verified and relevant for the study.

The study was conducted on the basis of surveys completed in small and medium size enterprises (SME) construction design companies in which activities are based on the preparation of design documentation. A structured survey consisting of two parts was used. The first part concerns team members' attitudes and opinions (team composition - TC, team task – TT and team process—TP) with a total of 31 questions, while the second part of the survey consisted of two questions (team satisfaction – TS and team performance - TP). Survey questions were formulated according to previous research conducted by Champion et al. (1993), Doleen, and according to guidelines provided by Van der Van and Ferry, after which they were adapted to the factor analysis examination of opinions and attitudes of team members within the construction design companies. A five-point Likert scale was used in the survey questionnaire, whereby 1 signifies “complete disagreement”, while 5 signifies “complete agreement”, as well as a nominal scale of satisfaction and project performance status. The adequacy of the final set of survey items obtained by factor analysis was measured by Cronbach's  $\alpha$ . A very good internal consistency (Cronbach, 1951) was confirmed by the obtained value (0.716).



### *Data collection and sampling*

The subject study was conducted in March 2019. Directors, designers and associates from several small and medium construction design companies that mostly cooperate on projects participated in the study. The total number of respondents is 77, whereby designers comprise the largest proportion of respondents with a total of 53.2%. Associates account for 35.1%, while directors account for 11.7% of the total number of respondents. Men (66%) were predominant among the respondents, which confirms the statistical study conducted by the Croatian Bureau of Statistics (2011) indicating that men choose to partake in the construction industry to a greater extent than women. The majority of respondents are of a younger age (25-35 years of age) and comprise 54.5% of the total number, followed by respondents aged 36-45 (18.2%), 46-55 (14.3%), more than 56 years of age (11.7%), and less than 25 years of age (1.3%). The majority of respondents work in teams consisting of 2-4 members (39%), while only 1.3% of respondents work independently.

### *Methods applied*

On the basis of the collected data, the application of factor analysis determined the variables relevant for the formation of a universal and original model in the form of functions, on which the correlation between team characteristics (independent variable) and their effectiveness (dependent variable) shall be determined by applying multilinear regression analysis. The collected data are processed and calculated using the statistical data processing software (SPSS).

The *team effectiveness* dependent variable was formed on the basis of the theoretical part of the study by the suggested subjective variable of *team members' satisfaction* and the objective variable of *team effectiveness* (completion on time and within budget) according to the models developed by Hackman (1987), Gladstein (1984), Sundstrom et al. (1990) and Doleen, Hacker, Van Aken (2006). Independent variables were formed and tested by factor analysis. The mutual dependence of the dependent variable and the independent variables was tested by multilinear regression.

## **4. Results and discussion**

### *Factor analysis*

Given that this is a survey with a large number of questions, factor analysis (*Principal Component Analysis – PCA*) was performed to determine the factors of correlation between variables, i.e. to reduce the dimensionality of the original space (Zahirović, 2005). A larger number of questions (variables) that are mutually covariant is reduced, by means of factor analysis, to a smaller number of factors (variables) explaining the covariances between the manifest variables (Fazlić & Đonlagić, 2016), including factor rotation for the purpose of obtaining interpretative variables (Kiss, 2011).

Factor analysis is an analysis used for a large number of samples, and the minimum acceptable absolute minimum of samples should be higher than 50 (De Winter, et al., 2009). In order to evaluate the psychometric properties of social constructs, such as the subject one,

appropriate sample size for the principal component analysis amounts to 50-100 (Sapnas & Zeller, 2002). On the basis of factor analysis, the extracted factors were interpreted by means of multilinear regression analysis, for which it is defined, as a rule of thumb, that the minimum number of samples is  $50 + 8k$ , where  $k$  is the number of predictor (independent) variables (Green, 1991), which in this case entails a minimum of 74 samples.

Factor analysis of the principal components for the team characteristics scale (TC, TT and TP) was performed in this study. Variables that are significant in terms of factor analysis, which affect the team effectiveness, were determined using factor analysis of characteristics, while less significant variables were omitted from the analysis. Of the 31 variables, 13 directly correlated with team effectiveness, and these variables form the basis of the subject study.

During the factor analysis, the Kaiser-Meyer-Olakin measure of sampling adequacy in relation to team characteristic variables, with the value of 0.567 (prescribed value  $> 0.5$ ), was determined, which confirms the adequacy of variables for factor analysis (Kaiser, 1974). The null hypothesis, with a starting point consisting of the assertion that there is no significant correlation between the original variables, has been rejected on grounds of the result of Bartlett's test of the null hypothesis ( $\text{sig} = 0.000$ ).

In the next step, the factor structure matrix was created, as well as the extracted factors matrix and the rotated factors matrices. It shows correlations of extracted factors and variables, as well as factor loadings that highlight the importance of each variable for each factor. The matrix results suggest that certain variables correlate with several factors. The first factor, which has the highest value in terms of explaining the manifest variables, has the highest loading, while the second and the third factor explain a smaller part of the total variance. Three factors explain a total of 54.48% of the factor variance, meeting the condition of the minimum acceptable value of variance (50%) in social research (Sarstedt & Mooi, 2014), where information is often less precise (Hair et al., 1998), while the communality values of independent variables were acceptable and all variables were included in the analysis.

Given that the matrix does not possess features of a simple structure, factor rotation is performed by orthogonal rotation of factors applying the "varimax with Kaiser normalization" method. This method, compared with other rotation methods, is more successful in realizing the simple structure principle (Harman, 1976) by simplifying columns in the factor structure matrix (Kurnoga Živadinović, 2004). In orthogonal factor rotation, the sum of squares of factor loadings for each individual variable after rotation must be equal to the sum of squares of these factor loadings before factor rotation, which was realized in this analysis.

On the basis of obtained factor analysis results, three factors were formed, representing the independent variables required for multilinear regression analysis, and their characteristics are indicated in Table 1:

Table 1. Characteristics of independent variables

FACTOR 1 - team task	
includes 6 variables and explains 26.16% of the variance	
TT_7	Work performed by my team is very important for the society
TT_18	Members of my team are willing to share information with other team members
TT_10	Most of the members of my team have an opportunity to learn how to perform new, different tasks and works
TP_27	My team can take on and finish almost any task
TP_30	Members of my team socialize after business hours
TP_31	The fact that I have an opportunity to support other team members pleases me
FACTOR 3 – team process	
includes 3 variables and explains 42.52% of the variance	
TP_22	Almost all members contribute equally to work
TP_24	In the event of a disagreement among team members, the problem was resolved by bringing the problem into the "open" and resolving it through conversation with the team members involved
TP_25	In the event of a disagreement within the team, the problem was resolved by ignoring it
FACTOR 2 – team composition	
includes 4 variables and explains 54.47% of the variance	
TC_3	Team members' level of education
TC_6	Average size of the team in which the team members work
TT_15	The team leader coordinates the performance of tasks that have been assigned to the team members
TP_20	Every person in my team is doing their part of the job

### *Multilinear regression*

On the basis of the three extracted factors, multilinear multiple regression with three independent variables (TP, TC and TT) and a dependent variable (TE) was performed in the study in order to determine the variability between team effectiveness based on the linear combination of team task, team composition and team process. The Enter method was used since independent variables were formed using factor analysis.

The accuracy of the model was evaluated on the basis of a descriptive analysis according to which the criterion variable of team effectiveness was described by standard error (Std. Deviation 0.388) whose value is acceptable and indicates that the data are very close to the mean of the set.

The first step determined the correlation relations between the dependent and the independent variable through the value of the Pearson correlation coefficient ranging from +1 (perfect positive correlation) to -1 (perfect negative correlation). The Pearson correlation relationship of variables in this study is acceptable and demonstrates a moderately strong correlation between team effectiveness and team task (49.8%, sig. 0.000), and between effectiveness and process (37.1%, sig. 0.000), while the correlation relationship between team effectiveness and team composition is moderate (26%, sig. 0.011). The sig. coefficient is used to describe the linear relationship between the dependent variable and independent variables,

with error of the first kind being 0.05, and it demonstrates the statistical significance of variables. Thus, the obtained values indicate statistically significant linear relationships between team effectiveness and predictor variables TC, TT and TP.

**Table 2. Model summary**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
2	,673 <sup>b</sup>	,453	,430	,29301	,068	9,03	1	73	,004

b. Predictors: (Constant), TP, TT, TC

Using the correlation coefficient R (0.673) a very good relationship between the dependent variable and independent variables was established (Colton, 1974), while the coefficient of determination (R<sup>2</sup>) explained 45.3% of the variability that can be explained by the population based on the linear combination of three predictor variables whose value is common in social research (Moksony, 1999). The corrected coefficient of multiple determination explains 43% of variability of the criterion variable based on the knowledge of variability on predictor variables, and it is relevant for the subject study.

The standard error of the estimate demonstrates the accuracy of the model, i.e. it demonstrates how many errors would occur on average when predicting results pertaining to the criterion variable based on a linear combination of predictor variables, with its value being 0.293 and it is not significantly higher than the standard deviation of the criterion variable of 0.388.

By testing the null hypothesis regarding the coefficient of multiple determination, it is proven that there is no relationship between the criterion variable and the linear combination of predictor variables, i.e. it is proven that the coefficient of multiple determination is zero.

$$H_0: P^2 = 0 \quad (1)$$

In this study, the value F is 9.03 with an acceptable corresponding probability value (sig. 0.000), which is less than 0.045, F is statistically significant, the null hypothesis of non-existence of linear correlation is rejected, and the regression model is acceptable for population analysis.

Ultimately, the multiple linear regression model for a population is determined on the basis of:

$$y_i = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_m x_{im} \quad (2)$$

where  $y_i$  is the predicted the value of the criterion variable, while  $\beta_0, \beta_1, \beta_2, \dots, \beta_m$  are model parameters (the constant and regression coefficients for  $m$  predictor variables).

**Table 3. Coefficients**

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
3	(Constant)	2,818	,033				
	TT	,193	,034	,498	5,748	,000	,126 ,260
	TP	,144	,034	,371	4,283	,000	,077 ,211
	TC	,101	,034	,260	3,006	,004	,034 ,168

It has been previously established that there is a linear relationship between the criterion variable and predictor variables, and the regression model in this study is formed on the basis of the results indicated in Table 3:

$$Y = 2,818 + 0,193x_1 + 0,144x_2 + 0,101x_3 \tag{3}$$

where:  $x_1$  – team task,  $x_2$  – team process,  $x_3$ - team composition

Based on the chart in Figure 2, it is evident that the test of normal distribution was successful.

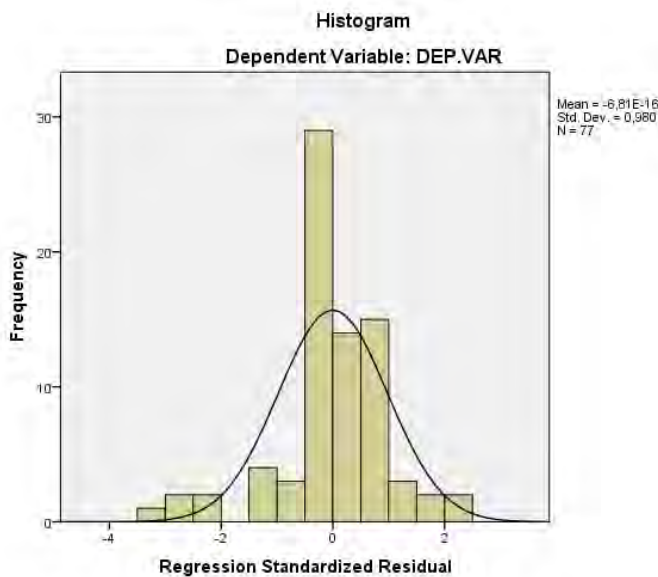


Figure 3. Dependent variable histogram

By testing the hypothesis of individual variables, their individual impact on team effectiveness is determined. The hypothesis whether TT exerts a significant impact on the increase in TE is tested. The null hypothesis is:

$$H_1: X_1 < \beta, \text{ while the alternative hypothesis is } H_1: X_1 > \beta, \beta=0 \tag{4}$$

The null hypothesis is rejected since  $\frac{0,193}{0,034} = 5,748$ , and it is concluded that TT is a significant predictor for increasing team effectiveness, assuming that other predictor variables do not change. The same hypothesis is used to determine the impact of an increase in TP, or TC on team effectiveness, assuming that the other variables remain unchanged. The hypotheses are rejected since for TP  $\frac{0,144}{0,034} = 4,283$ , while for TC  $\frac{0,101}{0,034} = 3,006$ . By testing the hypotheses, it is concluded that the team effectiveness is influenced by all three variables.

The 95% confidence interval indicates that, in case the situation regarding TC, TT and TP in a project team remains unchanged, the interval of team effectiveness ranges between 2.75-2.88%. For each increase in TT, the 95% interval ranges between 0.126-0.26 of increment units, for each increase in TP, the 95% interval ranges between 0.077-0.211 units while the 95% interval for TC ranges between 0.034 and 0.168 of increment units related to team effectiveness.

The predicted value of the dependent variable TE ranges between 2.08 and 3.15 with the arithmetic mean of 2.82 and its deviation of 0.26, which is an acceptable deviation as the standard error ranges from -2.82 to 1.25, which leads to the conclusion that the enhancement of team performance may reach up to 3.14, while a minimum increase with unchanged predictor variables may reach 2.07.

The chart (Figure 3) indicates that this is a growing linear regression of the dependent variable of team effectiveness.

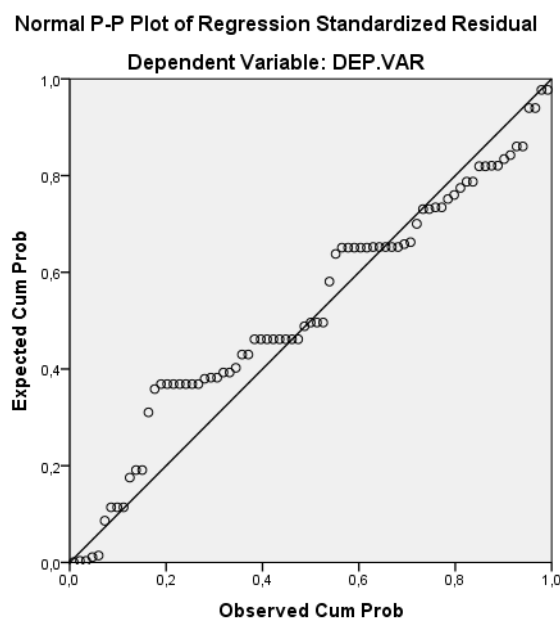


Figure 4. Regression model of team effectiveness

## 5. Conclusion

The team effectiveness dependent variable presented in the theoretical part of this paper is described by reference to 33 team characteristics. By factor analysis, the number of collected characteristics was reduced to 13 characteristics grouped into three factors - team process (TP), team task (TT) and team composition (TC), and a statistically significant correlation between

all three variables and team effectiveness was subsequently determined by multilinear regression analysis, and all three variables were included in the regression model.

Multilinear regression analysis determined that the team task variable had the highest correlation with team effectiveness (49.8%). More specifically and according to the analysis, by increasing TT by 1%, with TC and TP being constant, team effectiveness is increased by 0.193% in terms of preparing designs that are characterized by higher quality and within the prescribed deadlines, as well as overall work satisfaction. By analyzing the constituent characteristics of the TT variable, the following conclusions have been reached:

- The highest correlation factor was determined between team effectiveness and ***team members' awareness of having the opportunity to support other team members*** (Pearson coeff. 0.493, sig. 0.000). Support among team members and a team leader is crucial. A team leader should possess leadership skills, and not only accept responsibility when issues arise, but also give credit to each team member in case of successful projects. Such a manner of thinking and acting engenders trust and loyalty among team members by forming the attitude of the team (Hess, 2018) that each task can be performed at the highest level.
- A very significant correlation relationship was determined between team effectiveness and ***the willingness to share information with other team members*** (Pearson coeff. 0.485, sig. 0.000), i.e. cooperation. In every company, and consequently in teams, cooperation and communication between team members constitutes a "central feature of life" of the company and is a key factor for continuous improvements (Vogelsmeier, 2008) and team effectiveness. Cooperation among team members solves complex problems since each team member shares their perspective (Funk, 2014) on problem-solving and improving relations between team members.
- A significant impact on increasing team effectiveness is also exerted by the ***social significance of tasks that the team members perform*** (Pearson 0.414, sig. 0.000). When preparing designs that are of great importance for the community and performing it on time and within the budget, the importance of the members increases, and consequently their self-confidence and desire for further improvement, learning and educating themselves and working on improving their team, in order to become even more ready in the future for preparing such designs, increases as well.
- ***Self-confidence of team members*** to take on and complete almost every task (Pearson coeff. 0.271, sig. 0.017) is the next important characteristic. If team members' self-confidence is sufficiently developed, they will try to be successful in solving the tasks and will possess an inner need to avoid failure (Covington, 1984). A low degree of self-confidence can result in a number of problems that would not have occurred if a positive attitude and belief in their team had been present, since each group becomes a team when each member is sufficiently confident in themselves and their contribution so that it is possible for them to praise the skills of other team members (Hidle, 2013).
- An important characteristic that influences team effectiveness is a friendly relationship between team members ***who socialize after business hours*** (Pearson coeff. 0.287, sig.

0.011). Socio-emotional relations between team members, as well as a positive interpersonal environment, improve a team's creativity (Han, et al., 2019), and this study has also confirmed the effectiveness thereof.

In addition to TT, the team process variable has been proven to exert an impact on team effectiveness, and the correlation between them is moderately strong (37.1%). The regression model indicated that, by increasing team process characteristic by 1% at constant TT and TC, team effectiveness increases by 0.144%. Through a more detailed analysis of the TP variable characteristics, the following was established:

- The principal characteristic that exerts an impact on team effectiveness is classified under the sub-category of conflict management, i.e. ***resolving conflicts by ignoring them*** (Pearson coeff. 0.587, sig. 000). It is evident from the result obtained that the team members hold the manner of resolving conflicts important since conflicts are certain to arise in performing tasks due to differences in personalities and mindset. Apart from conflict resolution, it is important to recognize conflicts in time (Turkalj, et al., 2008), since ignoring conflicts does not contribute to problem being resolved, but rather to a temporary deferral thereof. By resolving conflicts in time, teams establish stronger collective identities, discuss difficulties and frustrations, and create solutions for resolving them for the benefit of the team (Zhang, et al., 2011).
- In addition to the manner of solving problems, a significant correlation between team effectiveness and an ***equal work contribution of each*** team member has been established (Pearson coeff. 0.211, sig 0.05).

The third variable is statistically significant as well as the previous two variables since increasing it by 1% results in increase of team effectiveness by 0.101%.

- The characteristic ***every person in my team is doing their part of the job*** contributes the most to increasing team effectiveness (Pearson coeff. 0.327, sig. 0.004). It is important for team members that every person does their job conscientiously in order for the project delays and unforeseen costs not to arise. Furthermore, trusting other team members to do their job properly facilitates their mutual exchange of information and insights, and consequently increases the team's self-confidence that the projects will be executed on time and in a quality manner. Trust among team members is built steadily, by establishing and developing confidence in each other's competencies and reliability (Mickan & Rodger, 2000), and therefore it is important to attribute great importance to this characteristic within the team in order to increase team effectiveness.
- In addition to the aforementioned, the role of ***the team leader who coordinates*** the performance of tasks assigned to team members is very important (Pearson 0.238, sig. 0.037). The role of the team leader is not confined to coordinating the execution of tasks, and it is complex since they primarily need to know all the team members and their competences in order to distribute tasks among team members in an optimal manner and select team members, which is a challenging issue in managing human resources since it includes different criteria, such as education and work experience (Caniëls, et al., 2019), as well as sociological characteristics.



- ***Average size of the team in which the team members work*** (Pearson 0.217, sig. 0.05). Although the statistical correlation between the size of the team and its effectiveness is weaker, the size of the team should not be omitted as an exploratory factor of team performance (Guzzo & Shea, 1992) in describing team effectiveness.

Based on the performed analyses, it can be concluded that team task, followed by team process and team composition exert an impact on team effectiveness the most. These findings allow for a better understanding of the attitudes and opinions of members and project team leaders, and provide valuable guidelines to scientists and managers on how to increase team members' satisfaction, while simultaneously completing projects on time and within budget, thus effectively performing project tasks. In further research, it would be interesting to see if the team members' age and the length of their practice in the company also have an impact on the results.

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# Determination of KPIs for Small and Medium Sized Construction Companies

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## Abstract:

Small and Medium Sized Enterprises (SMEs) make significant contributions to countries' economy in many ways. For instance, in Europe, 56,8% of total value added and 66,4% employment has been created by SMEs in 2017. Additionally, SMEs play important roles in Construction Industry (CI), especially in off-site manufacturing, and assembly and supporting services in construction sites. Therefore, performances of SMEs are crucial to complete construction projects successfully. CI has been criticized because of its underperformance and inefficient working environment. At this point, measuring the performance of construction companies using precisely developed Key Performance Indicators is a must and effective tool. However, current KPIs available in the literature have developed either for projects or large construction companies. KPIs for small and medium-sized construction companies have not been determined yet. Therefore, this study aims at determining KPIs convenient to SMEs in CI. Initially, 46 KPIs were extracted by conducting a literature survey and classified under 6 perspectives. Structured interviews conducted with the participation of 20 experts working in various SMEs for evaluating the determined KPIs. Based on the structured interviews, 12 of them are eliminated and 10 new KPIs recommended by experts are added. The second list consisting of 44 KPIs are re-evaluated by 5 highly experienced new respondents. Eventually, a final list of 37 KPIs is determined. The KPIs proposed in this study can be used by decision-makers in efforts to measure and boost the performance of their organizations.

*Keywords: KPIs; SMEs; performance measurement; construction industry*

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## 1. Introduction

The importance of SMEs for the countries' economies are beyond question since the vast majority of firms around the world are classified as micro, small or medium-sized enterprises (SMEs). For instance, 99.8% of enterprises in the EU-28 non-financial sector fall into the category of SMEs. In addition to this, SMEs have created 56.8% of total value added and 66.4% of employment in Europe as of 2017 (European Commission, 2018). SMEs are not only crucial assets for developed economies, but also play important roles for developing countries. For instance, they are capable of generating new income opportunities as well as employing the largest percentage of the workforce in developing countries. These enterprises can also be seen as one of the key factors for poverty alleviation (Singh et al., 2009). In addition, prior researches showed that SMEs have a great potential to boost the economy of countries. Consequently, the performance of SMEs is directly related to the performance and pace of nations (OECD, 2005).

Besides their importance for the macroeconomics of countries, SMEs also take active roles in the construction industry (CI). Especially, CI heavily relies on SMEs in areas of off-site manufacturing, on-site production assembly and supporting services (Betts and Wood-Harper, 1994; Carty, 1995; Halpin and Woodhead, 1998; Rezgui and Miles, 2010; Rezgui and Zarli, 2006). Additionally, SMEs are involved in large projects as sub-contractors as well as involving in small- and medium-sized projects as general contractors (Dlungwana and Rwelamila, 2004). Therefore, their performance is crucial to ensure that CI showing high performance. However, the performance of CI is mostly found insufficient by the authorities and researches (Barrett and Sexton, 2006; Rezgui and Zarli, 2006; Sexton and Barret, 2003). Even CI sadly performs the worst compared to other industries due to the highest rate of cancelled and challenged projects (Rounds and Segner, 2011). The problem lies in the fact that firms working in CI continuously confront with important and unprecedented challenges due to CIs' complex, dynamic and constantly changing environment (Davey et al., 2001; Rezgui and Zarli, 2006).

This current performance problems seen in CI calls for effective performance measurement which gives companies the possibility to manoeuvre in complex and constantly changing environment of CI. Kagioglou et al. (2001) defined performance measurement as the process of determining how successful organizations or individual in achieving their objectives. Therefore, owners-managers of organizations take necessary actions in case they realized that objectives are not going to be met. Consequently, for construction firms, measuring their performance and comparing with past performance are must to find out what should be improved (Gupta, 2004). Therefore, the applicable performance measurement systems should be developed to overcome the poor performance problems of CI. To design a performance measurement system, first of all, appropriate Key Performance Indicators (KPIs) has to be determined (Lin et al., 2011). Later on, conveniently determined KPIs must be measured, analysed, reported and stored inside the organization periodically (Parmenter, 2007).

In the construction management literature, there are studies conducted to determine the appropriate KPIs, however these studies focus on either projects or large companies (Chan and Chan, 2004; Cox et al., 2003; Enshassi et al., 2007; Radujković et al., 2010; Tripathi and Jha, 2018). Although small companies are convenient field to study the relationship between the implementation of specific management practices and organizational performance since they have more transparent structure (Sommerville and Robertson, 2000), no researcher has developed a set of KPIs specifically for construction SMEs, yet. Unfortunately, KPIs developed for large enterprises cannot be implemented on construction SMEs in engineering practice (Hudson Smith and Smith, 2007; Nudurupati et al., 2011; Turner et al., 2005), since construction SMEs confront with many unique challenges with respect to large companies. Those challenges include weak stance against market fluctuations due to limited resources and lack of experience (Smallbone et al., 2012); limited marketing skills of their owners-mangers (Callahan and Cassar, 1995; Carson and Cromie, 1990; Harris and Watkins, 1998; Siu and Kirby, 1998; Tang et al., 2007) and tendency of owners-managers to conventional business marketing models (Carson, 1990; Tang et al., 2007). Therefore, KPIs specific to construction SMEs must be developed. Consequently, this study aims at determining a list of KPIs which can enhance the performance of the construction SMEs which contribute considerably to both macroeconomics and CI of countries. Similar to the relationship between families and society, as the smallest units of CI, the performance of construction SMEs should be boosted to overcome the performance problems seen in CI.

Remaining sections of this paper are organized as follows. Firstly, relevant studies in the literature are going to be summarized. The methodology used in this study will then be presented. This is going to be followed by the Results and Discussion section. The conclusions are going to be made as the last section of this paper.

## **2. Literature Review**

Performance Measurement Systems have been studied by researchers since the early 1990s (Yu et al., 2007). Very first systems included only financial indicators. However, these systems were criticized, since these indicators show only the past performance rather than future performance. Eccles (1991) proposed that non-financial indicators such as market share, innovation should also be used to evaluate the companies from a broader perspective. Kaplan and Norton (1992) introduced a new concept called Balanced Scorecards (BSC) after a year-long research project with a participation of 12 companies. They concluded that using one single type of indicators cannot provide accurate results and suggested that managers must use a balanced presentation of both financial and operational indicators. Therefore, the BSC utilizes indicators obtained by considering four different perspectives, namely financial, customer, internal process, innovation and learning.

As stated before, appropriate KPIs should be determined to develop a performance management system. Cox et al. (2003) defined KPIs as a set of data measures used to evaluate the performance of organizations. According to Radujkovic et al. (2010), KPIs are useful tools to monitor and control the performance of organizations. Additionally, KPIs are used to measure the distance of an organization from achieving its objectives (Morrison, 2016). Consequently, KPIs play a key role in providing information on the performance of construction tasks, projects, and companies.

There are studies to determine KPIs. However, construction SMEs have been usually ignored so far. One of the first studies related to performance management in construction management literature was conducted by Cox et al. (2003). They developed KPIs for entire CI which can be implemented in both projects and corporates. To limit the complexity of the system, the authors used correlations to determine the most commonly used indicators. However, authors relied more on financial indicators such as Units/MHR, \$/Unit, Total cost etc. and this leads to a variety of shortcomings. Beatham et al. (2004) pointed out the shortcomings of the traditional performance measurement system by blaming that traditional models tend to show past performance. The authors classified indicators into two categories such as lagging (financial) and leading indicators (operational). Main disadvantages of lagging indicators are that they don't provide any opportunity to change. Additionally, the authors also made recommendations to employ KPIs precisely in CI. Chan and Chan (2004) developed a framework to measure the performance of construction projects. The validity of the proposed KPIs was tested by three case studies. Shahin and Mahbod (2007) proposed an approach which assists managers to determine the most relevant indicators with respect to the goals of enterprises. The proposed method was based on the analytical hierarchy process (AHP) technique and SMART criteria. The hotel project was used to validate the method. However, it was stated that the Method is applicable to all sectors. Luu et al. (2008) developed a performance measurement method for large construction companies in Vietnam by integrating BSC and strength-weakness-opportunities-threats (SWOT) matrix. Then, the method was validated through a case study with the participation of the AnGiang construction company.

Consequently, the authors concluded that the method is also applicable to other developing countries. Luu et al. (2008) proposed a set of KPIs which can be used for benchmarking of large construction contractors. The paper provided nine key performance indicators including both financial and non-financial terms. Another remarkable study which is specific to construction projects was conducted by Enshassi et al. (2009). The authors aimed to solve performance problems of construction projects in the Gaza Strip by highlighting the factors which affect the projects. The initial set of factors were extracted by conducting an in-depth literature review. Later, the most important factors affecting performance were determined through a questionnaire survey conducted on 120 experts. The most important factors were identified as delays due to material shortage, unavailability of resources, low level of project leadership skills, escalation of material prices, unavailability of highly experienced and qualified personnel, and poor quality of available equipment and raw materials. Radujkovic et al. (2010) conducted a very impressive study and investigated the significance, role and types of KPIs for the CI in South-Eastern European Countries. The authors used a similar methodology as Enshassi et al. (2009). 37 KPIs were determined through a comprehensive literature review. After, data gathered from 30 large construction companies and being analysed. Eventually, the top ten KPIs were determined based on the experts' view. The top ten KPIs are quality, cost, number of investor interferences, changes in project support, time increase, client satisfaction, employees' satisfaction, innovation and learning, time and identification of client's interest. One of the most comprehensive studies conducted by Ali et al. (2013) for large construction companies of Saudi Arabia. 47 row KPIs were extracted from literature and the most important ones were determined using relative importance index (RII). Therefore, proposed KPIs can be implemented either for benchmarking and performance measurement. The latest study was conducted by Tripathi and Jha (2018). The authors stated that most of the studies conducted in developed countries. However, construction firms in developing countries were mostly ignored by the researches. Therefore, the authors determined the most important KPIs extracted from literature through question survey with the participation of 106 experts. The top six indicators presented in the paper were profitability and asset management, the satisfaction of key stakeholders, predictability of time and cost, environment, health and safety.

A deeper look to the literature on performance measurement of construction companies and projects, however, revealed that there are no performance measurement system specifically developed for micro, small and medium-sized construction companies. Therefore, this study aimed to fill this gap.

### **3. Methodology**

The research methodology followed in this study is presented in

Figure 1. At the initial stage of this study, a comprehensive literature survey is conducted to extract KPIs. However, KPIs proposed for projects were not taken into consideration, since projects are temporary in nature and have other various differences with respect to construction SMEs. Based on this literature survey, 46 KPIs were determined and these KPIs and the references which state these KPIs are stated in Table 1.

At the second stage, KPIs were categorized based on the perspectives proposed in the BSC, however four main perspectives are considered as insufficient to measure the performance of the companies (Bourne et al., 2000; Schneiderman, 1999). Especially, when the complex and constantly changing environment of CI is considered, new perspectives are



required for CI. Therefore, in this study, two new perspectives were added into BSC to look at the matter of management from a wider window. The first perspective was determined as Environment due to the fact that all CI including construction SMEs has a hugely adverse effect on the environment (Banham, 2010; Zhi, 1995). Therefore, environmental concerns should be part of their management. Also, this perspective is suggested by Ali et al. (2013). The second perspective, namely external, was added, because of that it is agreed on that construction SMEs are weak against changes of the outside environment (Smallbone et al., 2012). Eventually, KPIs were classified into abovementioned six different perspectives based on the classifications proposed in the studies stated in Table 1 and this classification is presented in Table 1.

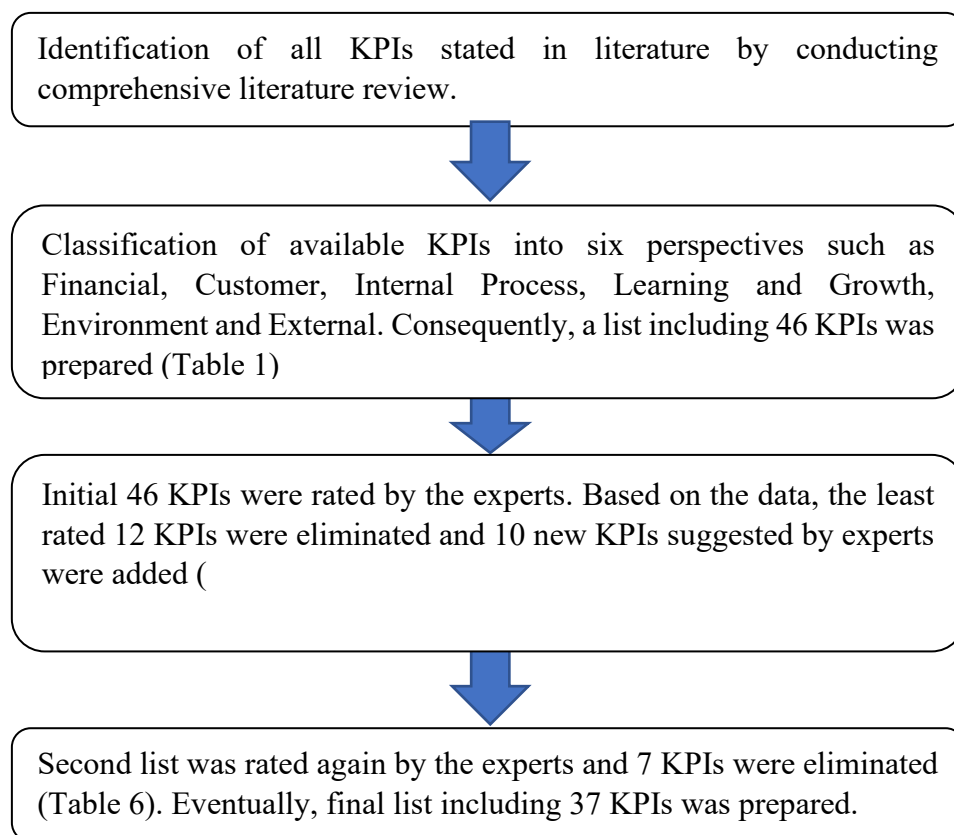


Figure 1. The research flowchart

Table 1. Initial List of KPIs extracted from the literature

	A	B	C	D	E	F	G	H	I
<i>Financial Perspective</i>									
Profitability	--	X	X	X	X	X	X	X	X
Reliability of Financial Performance	--	X	--	--	--	--	--	X	--
Growth	--	--	X	--	--	--	X	X	X
Financial Stability	--	--	X	--	--	--	--	X	--
Seamlessly Cash Flow	--	--	--	--	--	--	--	X	--
Capital	--	--	--	--	--	--	--	X	--
Interest Cover	--	--	--	--	--	--	--	X	--
Investment in Development of New Markets	--	--	--	--	--	--	--	X	--
<i>Customer Perspective</i>									
Internal Customer Satisfaction	--	--	X	X	--	--	X	X	X
Number of New Customers	--	--	--	--	--	--	--	X	--
Hassle-Free Relationship	X	--	--	--	--	--	--	X	X
External Customer Satisfaction	--	X	X	X	X	--	X	X	X
Quality of Service and Work	--	--	--	--	--	--	X	X	--
Market Share	--	--	X	--	--	X	--	X	X
Value of Money	--	--	--	--	--	--	--	X	--
Competitive Price	--	--	--	--	--	--	--	X	--
<i>Internal Process Perspective</i>									
Productivity	X	X	--	--	X	X	X	X	X
Innovation	--	--	--	--	--	--	X	X	--
Safety	X	X	--	X	X	X	--	X	X
Business Efficiency	--	--	X	--	--	--	X	X	--
Managers' Competency	--	--	--	--	--	--	--	X	--
Effectiveness of Planning	--	--	--	--	--	--	X	X	--
Labour Efficiency	--	--	--	--	--	--	--	X	--
Successful Tender Rate	--	--	--	--	--	--	--	X	--
Resource Management	--	--	--	--	--	--	--	X	--
Technological Capability	--	--	X	--	--	--	--	X	--
Quality Control and Rework	X	--	--	--	X	--	X	X	--
Defects	--	X	--	--	X	--	X	X	X
Research and Development	--	--	X	--	--	--	--	X	--
Staff Turnover	--	--	--	--	X	--	--	X	X
<i>Learning and Growth Perspective</i>									
Empowered Work Force	--	--	--	--	--	--	--	X	--
Informatization	--	--	X	--	--	--	X	X	--
Continuous Improvement	--	--	--	--	X	--	X	X	X
Human Resource Training and Development	--	--	X	--	--	--	--	X	--
Organizational competency in HR Management	--	--	X	--	--	--	--	X	--
Investing in People	--	--	--	--	--	--	--	X	--
Motivation	--	--	--	--	--	--	X	X	--

Table 1. (continued.)

	A	B	C	D	E	F	G	H	I
<i>Environmental Perspective</i>									
Impact on Society	--	--	--	--	X	--	--	X	X
Waste Management	--	--	--	--	X	--	--	X	X
Energy Use	--	--	--	--	X	--	--	X	X
Main Water Usage	--	--	--	--	X	--	--	X	X
Impact on Biodiversity	--	--	--	--	--	--	--	X	X
<i>External Perspective</i>									
Risk Control	--	--	--	--	--	--	--	X	--
Partnership and Suppliers	--	--	--	--	--	--	X	X	--
Changes in Policy or Law	--	--	--	--	--	--	--	X	--
Competitors	--	--	--	--	--	--	--	X	--

Key: **A:** (Cox et al., 2003); **B:** (Bassioni et al., 2004); **C:** (Yu et al., 2007); **D:** (El-Mashaleh et al., 2007); **E:** (Nemcova, 2009); **F:** (Horta et al., 2010); **G:** (Radujković et al., 2010); **H:** (Ali et al., 2013); **I:** (Tripathi and Jha, 2018).

At the third stage of this study, 20 experts working at various level of construction SMEs were asked to rate KPIs with respect to their importance on a five-point Likert scale. In this scale, 1 denotes the lowest importance and 5 denotes the highest importance. Data were gathered through structured interviews. These experts were selected by using judgement sampling; therefore, the background of each expert investigated deeply. Since this study focused on construction SMEs, it was crucial to choose experts from construction SMEs. The demographic structure of experts and their enterprises are presented in Table 2.

Table 2 The demographics of experts participating in the first step of the research

		Percent (%)	Count
Number of labours worked in the company	0-10 employees	25	5
	10-49 employees	50	10
	50-250 employees	25	5
	0-5	20	4
Experience of the companies (in years)	5-10	15	3
	10-15	25	5
	15-20	25	5
	Above 20	15	3
Yearly turnover of the company (in Turkish Liras)	0-1000000	15	3
	1000000-5000000	30	6
	5000000-10000000	15	3
	10000000-20000000	15	3
Position of the respondents	Above 20000000	15	3
	Manager	60	12
Degree of the respondents	Owner	40	8
	High school Degree	15	3
	Bachelor's degree	80	16
	Master's degree	5	1

Table 2. (continued.)

		Percent (%)	Count
Experience of the respondents (in years)	0-5	40	8
	5-10	20	4
	10-15	20	4
	15-20	10	2
	Above 20	10	2

Based on the data obtained through structured interviews, KPIs were ranked according to their mean values by employing a similar methodology as Tripathi and Jha (2018) (see Table 3). Firstly, the lower quartile of the sequence was calculated as 3.09. The KPIs whose means are less than the lower quartile were eliminated. At the end of the first analysis, 12 current KPIs were eliminated. Additionally, at the end of each category, experts were asked to add new KPIs into this category. 10 KPIs stated in Table 4 were recommended by experts, and these KPIs were added to the final list. Eventually, a second list consisting of 44 KPIs was designed to be used in the second survey.

Table 3 Ranking of KPIs based on experts' view

No	Key Performance Indicators	Mean
1	Quality of Service and Work	4.00
2	Hassle-Free Relationship	3.90
3	Safety	3.80
4	Business Efficiency	3.80
5	Effectiveness of Planning	3.80
6	Number of New Customers	3.75
7	External Customer Satisfaction	3.75
8	Productivity	3.75
9	Managers' Competency	3.75
10	Labor Efficiency	3.70
11	Internal Customer Satisfaction	3.60
12	Reliability of Financial Performance	3.55
13	Continuous Improvement	3.55
14	Partnership and Suppliers	3.55
15	Financial Stability	3.45
16	Empowered Work Force	3.45
17	Changes in Policy or Law	3.45
18	Market Share	3.40
19	Innovation	3.40
20	Resource Management	3.40
21	Research and Development	3.30
22	Growth	3.25
23	Organizational competency in HR Management	3.25
24	Motivation	3.25

Table 3. (continued.)

No	Key Performance Indicators	Mean
25	Value of Money	3.20
26	Technological Capability	3.20
27	Informatization	3.20
28	Impact on Society	3.20
29	Profitability	3.15
30	Competitive Price	3.15
31	Quality Control and Rework	3.15
32	Risk Control	3.15
33	Defects	3.10
34	Energy Use	3.10
35	Interest Cover	3.05
36	Human Resource Training and Development	3.00
37	Waste Management	3.00
38	Seamlessly Cash Flow	2.95
39	Capital	2.95
40	Investment in Development of New Markets	2.90
41	Successful Tender Rate	2.90
42	Competitors	2.85
43	Investing in People	2.70
44	Main Water Usage	2.70
45	Impact on Biodiversity	2.60
46	Staff Turnover	2.25

Table 4 Eliminated and Added KPIs

Added KPIs	Category
Rate of Return of an Investment	Financial Perspective
Resource Allocation	Financial Perspective
The Growth rate of annual revenue	Financial Perspective
Trust relationship with the customer	Customer Perspective
Customer Loyalty	Customer Perspective
Employee Satisfaction	Internal Process Perspective
Material Planning	Internal Process Perspective
Conformity to Standards	Environmental Perspective
Global Developments and Fluctuations	External Perspective
Market Conditions	External Perspective

The second survey was conducted by 5 highly experienced experts, and they ranked the importance of KPIs based on a five-point Likert's scale, where 1 denotes the lowest importance and 5 denotes the highest importance. These experts were different from the experts participated in the first survey, in other words, they did not participate in the first survey. Demographic distribution of these experts and their companies is presented in Table 5. Similar steps were followed as it was done in the previous section to determine the most appropriate list of KPIs for construction SMEs. 44 KPIs were ranked respect to their mean values, and 7 KPIs whose means are lower than the lower quartile calculated as 3.4 were eliminated. Eliminated KPIs from the second list and final list of KPIs with their mean values were presented in

Table 6 and

Table 7, respectively. Consequently, a final list of 37 KPIs was determined and this list was examined by the same experts, and all experts agreed upon the final list.

Table 5 The demographics of experts' participation in the second step of research.

		Percent	Count
Number of employees	0-10 employees	40	2
	10-49 employees	20	1
	50-250 employees	40	2
Experience of the companies (in years)	2	20	1
	10	20	1
	12	40	2
	20	20	1
Position of the respondents	Manager	40	2
	Owner	60	3
Degree of the respondents	High school Degree	--	--
	Bachelor's degree	60	3
	Master's degree	40	2
Experience of the respondents (in years)	2	20	1
	4	20	1
	6	20	1
	8	20	1
	15	20	1

Table 6 Eliminated KPIs from the second list

Eliminated KPIs	
Material Planning	Internal Customer Satisfaction
Technological Capability	Value of Money

Table 7 Final List of KPIs and their mean values

No	Perspective	Key Performance Indicators	Mean
1	Customer	Quality of Service and Work	4.8
2	External	Market Conditions	4.8
3	Customer	External Customer Satisfaction	4.6
4	Customer	Customer Loyalty	4.6
5	External	Changes in Policy or Law	4.6
6	Financial	Rate of Return of an Investment	4.4
7	Customer	Number of New Customers	4.4
8	Internal Process	Managers' Competency	4.4
9	Internal Process	Labor Efficiency	4.4
10	Environment	Energy Use	4.4
11	Financial	Financial Stability	4.2
12	Financial	The Growth rate of annual revenue	4.2
13	Internal Process	Productivity	4.2
14	Internal Process	Quality Control and Rework	4.2
15	External	Risk Control	4.2
16	External	Partnership and Suppliers	4.2
17	Internal Process	Safety	4.0
18	Internal Process	Business Productivity	4.0
19	Learning and Growth	Continuous Improvement	4.0
20	Financial	Profitability	3.8
21	Customer	Hassle-Free Relationship	3.8
22	Customer	Competitive Price	3.8
23	Customer	Trust relationship with the customer	3.8
24	Internal Process	Effectiveness of Planning	3.8
25	Learning and Growth	Empowered Work Force	3.8
26	Learning and Growth	Motivation	3.8
27	Environment	Impact on Society	3.8
28	Financial	Growth	3.6
29	Internal Process	Innovation	3.6
30	Internal Process	Defects	3.6
31	Financial	Reliability of Financial Performance	3.4
32	Financial	Resource Allocation	3.4
33	Customer	Market Share	3.4
34	Internal Process	Resource Management	3.4
35	Internal Process	Research and Development	3.4
36	Internal Process	Employee Satisfaction	3.4
37	Learning and Growth	Informatization	3.4

#### 4. Discussion of Findings

In his book, Parmenter (2007) stated that the number of KPIs which will be used to measure the performance of companies should be limited to ten. Therefore, the top ten KPIs presented in Table 7 will be discussed deeply in this section. According to results, at first, it is realized that 9 KPIs among top ten KPIs were non-financial indicators. This shows that BSC used in this study is a convenient technique to implement in today's construction SMEs. If only financial indicators were used in this study, the results would be insufficient from many aspects. Secondly, external indicators ranked highly important by the experts participated in this study. Therefore, authors do not hesitate to say that it was the right decision to add external perspective to BSC.

Customer-oriented KPIs are at the center of almost all performance measurement systems. Because, at the end of the day, customers are the one who will purchase the product or service offered by firms. In this study, customer-oriented indicators were also located at the center by the experts as similar to other studies such as Radujkovic et al. (2010), Ali et al. (2013) and Tripathi and Jha (2018), Namely, four indicators out of ten were customer-oriented indicators. It should be noted that, as one of the terms of Iron triangle perspective, Quality of service and work was rated as the most important indicator by the experts. The reason behind this tendency of experts is that the main assessment criterion for the construction products or service is its quality.

Market Conditions and Changes in policy or law were rated as highly important KPIs by the experts of construction SMEs, however, these indicators were not considered as important in studies conducted on large companies (Ali et al., 2013; Radujković et al., 2010). This was interpreted as the indication of that dynamics and needs of construction SMEs are different than large companies. Therefore, the specific performance measurement system must be developed for construction SMEs. Otherwise, it would be imprecise to implement indicators proposed by other studies conducted on large enterprises on construction SMEs. Explanation of this tendency of experts lies in the fact that SMEs are sensitive to macroeconomic fluctuations compared to large companies (Smallbone et al., 2012). Changes in policy or law also have an impact on the performance of construction SMEs. This phenomenon was explained by Smallbone and Welter (2001). Authors concluded that governments may act like either enabling and/or constraining force through policies or laws. If the governments act like constraining force, mainly two types of costs arise from these changes. Firstly, direct costs which fall on the companies such as the cost of employers' social security and secondly, the compliance costs which are defined costs of adapting to changes. Main reasons for compliance costs are dealing with additional paperwork and recruiting extra qualified or unqualified workforce to carry out additional tasks (Bannock and Peacock, 1989). Consequently, the authors stated that these costs



are relatively higher for SMEs than large enterprises due to their limited resources. This may be the reason why these indicators were not rated as important in other studies conducted on large enterprises.

Another remarkable point is hidden in

Table 4. Except for the energy use, all environmental-oriented indicators were eliminated at the end of the first survey due to their low score. Beyond this, any new environmental-oriented indicators have not been recommended by an expert. To the authors' knowledge, there might be two possible reasons for this current preference of experts. The first reason is the reluctance of owners-managers of construction SMEs to reduce their impact on the environment due to their tendency to focus on short term profits (Loucks et al., 2010). Secondly, experts might disagree with the idea that environmental indicators can be a measure of performance. They might think that their duty over when they meet the requirements of current laws.

## **5. Limitations of the Study**

Just like other studies, this study comprises several limitations such as bias, variance, timing, or even problems in the research process. Potential limitations of this study are summarized as follows:

1. This survey was conducted for construction SMEs in Turkey; therefore, the current socio-economic status of Turkey, such as government policies, regulations, and the investment environment, had effect on preferences of experts. In addition, some of the indicators may be specific to Turkey; therefore, some of the indicators can be eliminated in the studies conducted for different countries, and different indicators could be potentially added.
2. The number of respondents was another limitation of this study which can lead to bias. However, the background of respondents was investigated deeply, and their demographics were presented apparently in this study.
3. Simple statistical methods were adopted in this study. However, the more sophisticated multi-criteria decision-making (MCDM) methods such as AHP could be used.

## **6. Conclusions and Recommendations**

The construction industry is a very important part of the economy, especially in developing countries such as Turkey and Croatia. Unfortunately, CI is continuously berated for its underperformance by government bodies and professional chambers, which, in turn, put a lot of pressure on both construction companies and academics to find a solution to this problem. To the authors' knowledge, at this point, developing an accurate performance measurement system is a must and vital. By adopting performance measurement systems, firms can measure their performances and take necessary actions when they think that it is necessary. However, although construction SMEs are a weighty portion of CI, the matter of their performance has not been studied yet by the academics. Current studies focus either on projects or large construction companies. Therefore, to fill this gap, this study aims to determine the list of KPIs which can be used to measure the performance of construction SMEs accurately. Traditional performance measurement systems were criticised many times in literature because they

employed only financial indicators which cause inability to show future performance. However, the performance measurement system proposed in this study measures the performance of enterprises from six different perspectives, namely, *Financial, Customer, Internal Process, Learning and Growth, Environment and External* perspectives. In other words, two new indicators were added to those of the BSC. Environment perspective was added due to the fact that all construction companies harm the environment. Therefore, they must monitor their environmental impact continuously during their managerial process. External perspective was added because, in general, SMEs including construction SMEs are prone to variations in outside of the organization. The methodology followed in this study consists of 2 step questionnaire survey conducted on various experts working at various levels of construction SMEs in Turkey. Initially, 47 rows of KPIs were extracted through an in-depth literature review. Later on, these indicators were classified with respect to 6 different perspectives and eventually, the first list of KPIs was prepared to be used at the first step of the questionnaire survey. 20 experts participating in this study were asked to rate KPIs in the first list with respect to their importance on a five-point Likert scale. After, KPIs were ranked with respect to their mean values and indicators whose mean is lower than the lower quartile were eliminated due to their low score. At the third, section of the questionnaire, respondents had an opportunity to offer news KPIs which they think that it is important. Consequently, 12 indicators were eliminated while 10 new indicators were added. At the second step of this study, the same methodology as in the first step was followed, however, at this time, 5 different experts participated, and experts were not able to add new indicators. Finally, the final list consisting of 37 KPIs were formed.

According to results, it was realized that 9 KPIs out of the top ten were non-financial indicators. This showed how much the BSCs' suitable for construction SMEs. Secondly, indicators were classified under the external perspective obtain a higher score from the experts. Therefore, authors deduced that the decision of adding external perspective into the BSC concept was the right decision which was also approved by decision-makers. Unlike the other studies focusing on large companies, in this study, indicators named as market conditions and changes in policy or law were rated as highly important by the experts. This shows that preferences of experts of construction SMEs are different than those in large companies. Therefore, there is a need for the development of a performance measurement system specific to construction SMEs. However, the results of this study also show similarity to other studies focusing on large companies in terms of customer-oriented indicators. For instance, customer-oriented indicators such as Quality of Service and work rated as the most important indicator by the experts. Interestingly, most of the environment-oriented indicators were eliminated at the end of the first questionnaire survey. There are two possible reasons for this tendency experts. However, likely, this shows owners-managers of construction SMEs unwillingness to reduce their environmental impact. Therefore, the required laws must be introduced to force them to act in favour of the environment to protect future generations. Otherwise, decision-makers of construction SMEs are not seemed to take some initiative.

In engineering practice, this study can be implemented in three different ways by the decision-makers of construction SMEs. Firstly, owners-managers of construction SMEs who wants to measure the performance of their enterprises using KPIs can directly use the top ten indicators proposed in this study. Since prioritization was made based on experts' view, a consensus was reached for indicators proposed in this study. Secondly, owners-managers of construction SMEs can determine their own top ten KPIs using the methodology used in this study. Thirdly, the proposed indicators could be also used in the Benchmarking of companies.

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# Method for Early Base Estimation of Construction Time for Linear Projects

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## Abstract:

Even though linear infrastructure projects have low complexity schedules, they are still not successful in meeting planned deadlines. The deadlines are mostly based on planning done in early project development when limited data are available. Developed models for early time estimations found in literature rely on few variables and, almost in all cases, one of them is estimated cost. This presents a problem because early cost estimations can significantly deviate from contract price and thus lead to unreliable time estimation. Most of the models found relates to high-rise buildings and linear projects are less represented in the literature of early time estimation. The purpose of this paper is to develop the method for early estimation of construction time for linear projects with repetitive activities which does not rely on estimated cost. This research is done on one large sewer system project. In case study we showed how to determine the small number of leading repetitive activities which stretches along the pipeline route. Then we elaborated algorithm for time calculation of activities in linear schedule method (LSM) which directly links durations of activities with quantities and estimated production rates. Developed method is based on project leading activities and algorithm and we showed an example of how to estimate the time by using this method. Limitation of this method is that it can be used only for base estimation. Further research needs to be done to develop method into a model and to include uncertainties and risks.

**Keywords:** *construction time estimation; linear infrastructure projects; method; deadline;*

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## 1. Introduction

Problem with construction time overrun in construction projects is well known (Bromilow, 1974; Bromilow et al., 1980; Chan and Kumaraswamy, 1995; Assaf and Al-Hejji, 2006; Chou and Tseng, 2011; Mahamid, 2016). One part of the problem lies in the fact that determined deadlines are based on estimates of project duration made in early phases and those predictions can be inaccurate (Radujkovic and Car-Pusic, 2006). Topic of early time estimation is not new in construction and project management literature, but there are only few models of time estimation and they are mostly based on project cost (Bromilow, 1974; Bromilow et al., 1980; Chan and Kumaraswamy, 1995). Most of these models are used to record what is likely to be achievable based on experience with past projects (Czarnigowska and Sobotka, 2014). Those existing predictive models are based on regression between cost and other project variables and duration (Bromilow et al., 1980; Chan and Kumaraswamy, 1995; Kaka and Price, 1991; Chan, 2001) and those variables incorporates risks and uncertainties in time prediction. However, some scholars are pointing on the fact that cost estimates can be very inaccurate (Assaf and Al-

Hejji, 2006) thus usefulness of the models is questionable. Even though, Hoffman et al (2007) did prove significant correlation between project cost and time, construction duration of projects in one business unit of large construction company they examined was lower than predicted. Authors argued that maybe this could be due to factors such as work ethic, labor and equipment and others.

Chan and Kummaraswamy (1995) stated that site labor productivity is significant intrinsic factor affecting the overall construction duration. Some scholars are claiming that construction activities and their embedded production rates should be more emphasized in time planning and time estimation (Lucko et al., 2014). During project execution, project activities are subject to uncertainties meaning that activities may take more or less time than originally estimated (Herroelen and Leus, 2005), thus if time estimation is based on deterministic time of construction activities it can be considered only as base estimation e.g. risks are not included. While early (base) time estimation is not a very highly researched topic in linear projects there are numerous papers dealing with time planning of linear projects (Arditi et al, 2002, Matilla and Park, 2003, Duffy et al, 2011, Lucko et al, 2011) which is usually done in preconstruction and construction phase. There is increasing interest in Linear Scheduling Method (LSM), chosen by many authors as the best solution for time planning of linear infrastructure projects and it applies to distance-based (alignment-based) projects, in example pipelines and highways construction projects (Arditi et al., 2002; Duffy, 2009; Lucko et al., 2014). There are only few variables needed to calculate the project duration using LSM (Lucko et al., 2014), e.g. production rate and quantity of work related to construction activities and these variables can be determined in early phase through preliminary design and bill of costs.

In this paper early time estimation is examined for linear projects with continuous and repetitive activities. Early time estimation is important for setting the construction project deadline and enable planning and control for contractors and project managers. There are not many models for early time estimation available and there is weak evidence of their usefulness. Field of early time estimation is still being examined by scholars and practitioners and there is need to expand topic of productivity related time estimation and planning as alternative approach to existing time estimation models and techniques. Therefore, this paper will present a method for early base time estimation of linear construction projects based on LSM scheduling technique.

## **2. Literature review**

### *2.1. Models for early time estimation*

In the construction industry, contractors usually use previous experiences to estimate the project duration and cost of a new project. The first early estimation of construction time performance of building projects was given in Australia in the late 1960s. After analyzing the performance of 329 Australian building projects in 1967, Bromilow et al. (1980) proposed the relationship between construction duration and the construction cost of the building projects to be of the formula:  $T=KC^B$ , where T is the duration of the construction period from possession of site to practical completion, measured in working days; C is the final project cost in A\$ million, adjusted to a price index; K is a constant describing the general level of time

performance is for an A\$ 1 million project; and B is a constant describing how time performance is affected by project size as measured by cost. The equation describes the mean construction time as a function of project cost. Chan and Kumaraswamy (1995) tested these relations on a small sample of infrastructure projects in Hong Kong (table 1). The R value indicates the coefficient of correlation, which is used as an indicator of the variability of points within each category and for comparison between categories.

**Table 1 Time-cost performance for civil engineering projects in the Hong Kong expanded sample (Chan and Kumaraswamy (1995))**

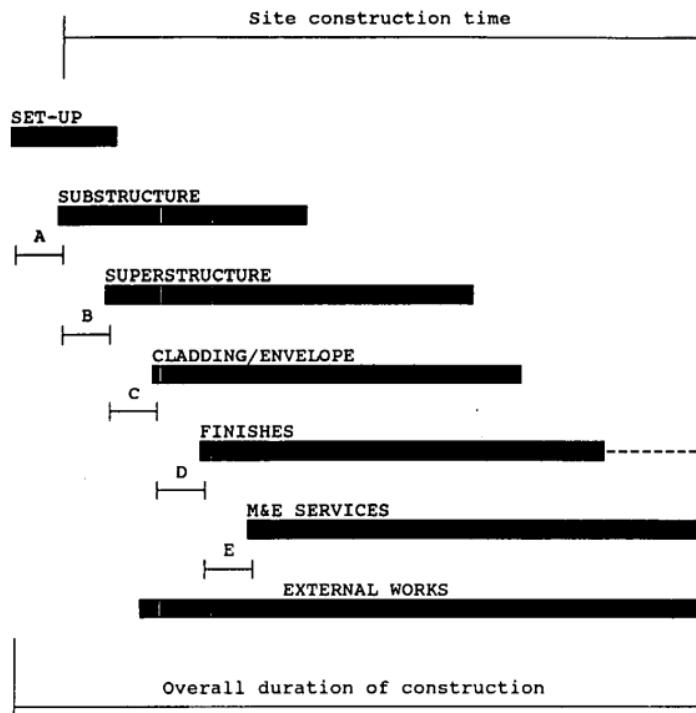
Project type	K	B	R	Total projects
Total civil works	250,5	0,206	0,79	148
Roadworks	251,2	0,225	0,87	57
Other civil works	262,5	0,185	0,69	91

Cost represents a sensitive variable based on overruns caused by higher overhead costs because of longer work period, higher material costs through inflation, and due to labor cost increases (Kenley, 2005; Assaf and Al-Hejji, 2006). A study on high-rise projects in Indonesia found out that cost overruns occur more frequently and are more severe problem than time overruns (Kaming et al., 1997). Some researchers suggested and developed multiple regression model of construction duration with more independent variables other than cost to offer more precise estimates (Czarnigowska and Sobotka, 2013; Hoffman et al, 2007; Walker and Shen, 2002; Gray and Little, 1985). With using CART regression tree as a method for determination of the viability of 25 selected project qualities used in formerly developed models, Czarnigowska and Sobotka, (2014) tested the formerly developed models. This research showed that actual cost exceeded the range of planned cost but regression tree also showed that cost is most accurate parameter of all 25 examined variables for time estimation. Czarnigowska and Sobotka (2014) then elaborated that cost estimates can be a valid parameter for time estimation but also stated that developed models based on costs are not very reliable and useful in practice and requires further development.

## *2.2 Defining the construction project duration through leading construction activities*

Models for early time estimation with multiple variables can be split into two groups: those which are orientated on project characteristics, aforementioned in subchapter 2.1, and those which are oriented on a set of activities (Radujkovic, 2012). Gray and Little (1985) have shown that there are several leading phases and processes in every construction project. Nkado (1992) defined activities for the construction of new buildings and described them through (independent) variables which are essential for calculating their duration. Peer (1974) suggests the development of time calculation of activities based on input of fundamental production variable, e.g., quantities of work, production rates of working group and other production characteristics. Activities can be categorized into major work packages to form an outline construction program (Nkado, 1992) presented in figure 1.





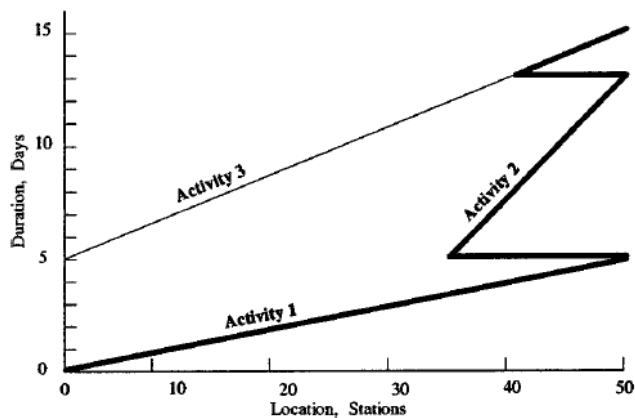
**Figure 3: Simplified outline construction plan based on condensed work packages (Nkado, 1992)**

Radujkovic and Car-Pusic (2006) analyzed and compared most of early time and cost prediction models and found some models which are oriented on set of major construction work packages (activities) along with some other project characteristics. Nkados (1992) master plan (Fig. 1) shows several leading group of activities (work packages) underlining duration of construction projects which he presented through traditional scheduling techniques (e.g. critical path method – CPM, and bar-chart) for determination of construction time. Critical path method (CPM) and other network planning methods haven't shown as the most effective planning tool for linear project with repetitive activities (Hamerlink, 1998; Hamerlink, 2001; Duffy, 2009; Abbondati et al., 2016). Hamerlink and Rowlings (1998) and Duffy (2009) stated several major construction activities for pipeline projects that represent most important contributors of project duration. In both papers, Linear scheduling method (LSM) is used to portray these planned activities.

### *2.3 Planning the linear projects with Linear Scheduling Method (LSM)*

In recent decades, the problems and limitations of traditional network-based scheduling techniques (i.e not considering location in which construction activity takes place) for linear projects have been identified by many studies (Harmelink, 1995; Adeli and Karim, 1997; El-Sayegh, 1998; Damci et al., 2013a). There are numerous time-location types of linear scheduling techniques in which one axis represents the time, and other represents the location which can be seen in figure 2. Two most known linear scheduling methods are Line of Balance and Liner Scheduling Method (Su and Lucko, 2015) with main difference in graphical representation of activities (e.g. activity is represented in LSM with one line and in LOB with two parallel lines) and some related characteristic i.e. time, quantity and slope measurements. LSM is slightly more well-known (Su and Lucko, 2015) which can be seen from numerous papers dealing with LSM related topics (Hamerlink, 1995, Harmelink and Rowlings 1998,

Mattila and Park, 2003, Duffly 2009, 2011). Rowings and the Iowa Department of Transportation developed an algorithm that determines the critical path in a linear schedule which is also called the linear scheduling model (LSM) (Hamerlink, 1995). It identifies the critical activities or the controlling activity path (CAP) (Hamerlink, 2001) which can be seen in figure 2. The CAP identifies which activities are controlling activities and which activities are non-controlling activities and deals with possible changes of their production rate which is a major attribute that determines (activity) criticalness (Arditi et al,2002).



**Figure 4 Example of controlling activity path (CAP) in linear schedule (Mattila and Park, 2003)**

There is no explicit equation for time calculation in papers dealing with CAP (Hamerlink and Rowings 1998, Matilla and Park 2003) and controlling path is determined from graphical representation of LSM schedule. To determine project duration based on CAP, linear schedule must be fully developed which mostly is not the case in early project phases. However, early ideas of LOB and LSM are related to production rate of continuous full-span linear activities which was also called production lines (Peer and Salinger, 1972, Peer, 1974 and Arditi and Albulak, 1986) and their concept was to develop several major production line (activities) and based on them calculate the total project duration.

#### *2.4 Using Linear Scheduling Method (LSM) for estimation of project duration*

Hamerlink (1995) provided classification of activity types in LSM and there are 4 types of linear repetitive activities; continuous full-span activities; intermittent full-span linear and two types of partial-span linear activities. Examining the history of line of balance (LOB) and related linear scheduling method (LSM), it can be seen that their origin is in manufacturing industry (Lucko et al, 2014, Su and Lucko 2015) where schedule was represented mostly by several parallel production lines. Objects of scheduling a repetitive process are: 1. Programmed rate of completed units, 2. A constant rate of repetitive work is maintained, 3. Labor and plant move through the project in a continuous manner (Arditi and Albulak, 1986). First examples of LSM and LOB showed full-span activities with synchronized performance (production rate), similar to industrial mass production where synchronization means planning a similar targeted output rate for all activities (Kolhe et al., 2014). Linear projects such as roads and pipelines are by nature characterized by a set of continuous full-span linear activities, e.g. which carrying out involves the whole development of the site without interruption (Abbondati et al., 2016). For this type of linear projects, it is possible to use equation provided in literature (Peer and Salinger

1972, Peer 1974). Peer and Salinger (1972) defines parameters for total construction time as followed:

$$T_t = T_i + T_s + T_b + \Delta T_d - \Delta T_v - \Delta T_r + \Delta T_m \quad (1)$$

$T_t$  =total construction time

$T_i, T_s$  = Preparation time

$T_b$  = Basic time

$\Delta T_d - \Delta T_v$  = Time increment due to change of direction

$\Delta T_r$  = Time increment due to external operations

$\Delta T_m$  = Time increment for small projects

$$T_b = k(n - 1) + \sum_{i=1}^n t_i + k \times m \quad (1a)$$

$m$  = Number of sections

$n$  = Number of production lines

$t_i$  = Waiting interval after line  $i$ , dictated by the production process

$k \times m$  = Overall time requirement of the last production line

All variables of the equation 1, except  $T_b$  (equation 1a), are dependent of some project characteristics of high-rise building projects which are not applicable to every linear schedule. Parameter  $T_b$  considers the main part which includes activities in linear schedule and buffer time between them. Equation 1a for basic time is very similar to equation 2 for calculation of total project time in LSM found in Radujkovic (2012) where variables and graphical representation (figure 3) are depicted plain and simple and therefore easy to understand. Examining the equation 2 it can be seen that total project time is calculated as a sum of preparation time, buffer time between activities (e.g.  $y_1$  is buffer time between activities A1 and A2) and duration of last activity.

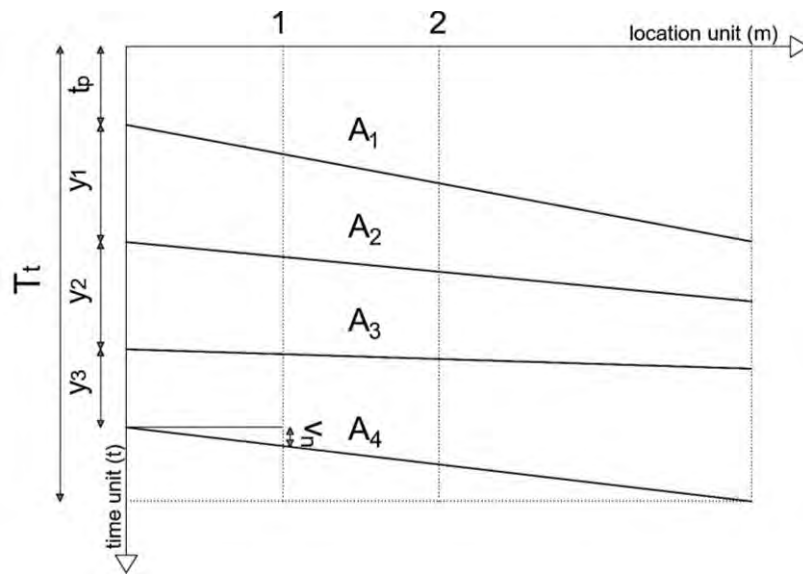


Figure 3: Graphical representation of the equation of Total project time in LSM (adapted from Radujkovic, 2012)

$$T_t = t_p + \sum_1^{m-1} y + m \times v_n \quad (2)$$

$T_t$  = Total time

$t_p$  = Preparation time

$y$  = Buffer time between two adjacent activities

$m$  = Location unit

$v_n$  = Production rate

$m \times v_n$  = Overall duration of the last activity

Time buffers indicates the required time lag between activities that ensure continuity of work (Kolhe et al., 2014) but it is dependent of the slope of every two adjacent activities. Figure 3 shows that there are situations where the slope of two adjacent activities can be the same or different. In situations of different slopes, the adjacent activities can converge or diverge. Slope of activity is proportional to the production rate which can be determined as quantity of work divided by duration (Su and Lucko, 2015) or if we observe duration (time) as an unknown variable then we reverse the equation and calculate the activity duration as quantity divided by production rate of activity work group.

The question is how to determine a set of continuous full-span linear activities and time buffer ( $y$ ) between each pair of adjacent activities without the need of developing detail linear schedule? Put differently, the question is how to use LSM and related formula for time estimation in early development phase?

## *2.5 Research justification*

Literature review showed that problem of early time estimation is still not addressed properly and emphasized the shortage of early time estimation models for linear infrastructure projects like pipelines and roads. Early development phase of project is characterized by scarce information and cost is one of them. Cost is part of almost every model for early time estimation and it has been proven by some scholars that early estimated cost can be unreliable comparing to actual costs and thus existing models can be inaccurate in their time estimation. We believe that it is necessary to develop new approach to early time estimation for linear infrastructure projects. We propose that activity based early time estimation is more reliable since the basis of estimation is the best prediction of the quantities and production rates which are associated with the delivery of a given scope of work and scholars are pointing to expand this type of time estimation and planning. In line with that, LSM technique is proven to be the best scheduling method for linear project but it is not used for early time estimation. Therefore, some aspects of LSM will be examined in more depth in order to bring improvements to early time estimation of construction projects. In this paper we will develop early time estimation method based on other variables beside estimated costs and thus broaden the field of early time estimation for linear infrastructure projects.

### **3. Methodology**

In this section we will present methodology containing several steps which resulted with development of the method for early time estimation of linear projects. Case study is done on one large sewage system, organized in LOTS, each LOT containing several pipelines. Pipelines are considered as a linear project, determined by linear repetitive activities. We choose one pipeline, which represents the most complex situation (e.g. highest number of different linear repetitive activities), for the development of the method in this case study. We choose this particular pipeline in order to be able to generalize results on other less complex pipelines in sewer system project that we studied. After the method was developed on one pipeline project, we verified it on another pipeline thus showing how to use the method.

#### *Step 1- Project analysis*

Sewage system examined in paper is classified as a separate sewer system, which means that sanitary waste water from the household and wastewater of service-industrial zones is drained by fecal sewage, while the precipitation water is drained by pre-sewerage, which is partially built. The system, which was studied consists of 3 LOTS. LOT 1 contains nine pipeline projects, LOT 2 has seven projects and LOT 3 has six projects. Technical description, bill of quantity and drafts are given for all projects and this documentation is studied thoroughly.

#### *Step 2- Representative pipeline project*

After thorough research of each pipeline project, the most complex one has been identified and for this project several critical (leading) time (and cost) related activities were detected. Representative project, that was chosen, included all types of works that can be found in all other pipeline projects documentation. Few pipeline projects include large engineering

buildings but these pipeline projects are not considered as normal (other) linear pipeline projects and should be planned differently and thus they were excluded.

### *Step 3 - Developing linear schedule with major leading activities*

All activities were detected and their production rate were calculated. Leading activities are taken into account because they are predictive for total project duration because they carry vast majority of the work. The activities were sequenced in the order in which they are typically performed. By using software TILOS, a base linear schedule was planned.

### *Step 4- Identifying important elements for development of algorithm based on LSM related equation*

In the process of schedule optimization, schedule was thoroughly analyzed. Four possible time-location situations between two adjacent activities were found and classified. Variables necessary for calculating the duration of an activity were identified. These variables allow us to calculate the production rate of each leading activity which are presented as a line in LSM. Based on the production rate dependency between two activities, a minimum buffer  $y$  is determined for all situations and the equation for its determination is given.

### *Step 5- Developing the algorithm and the method for base time estimation of linear construction project*

The relationships between all adjacent activities were identified and minimum time buffers were calculated. As buffer  $y$  is in dependency with few variables, these variables were extracted and an algorithm for total duration is developed. This algorithm calculates the project duration and it give the same result of time estimation as it can be seen from the developed linear schedule thus but without the need to make one.

### *Step 6- Verification of the developed method*

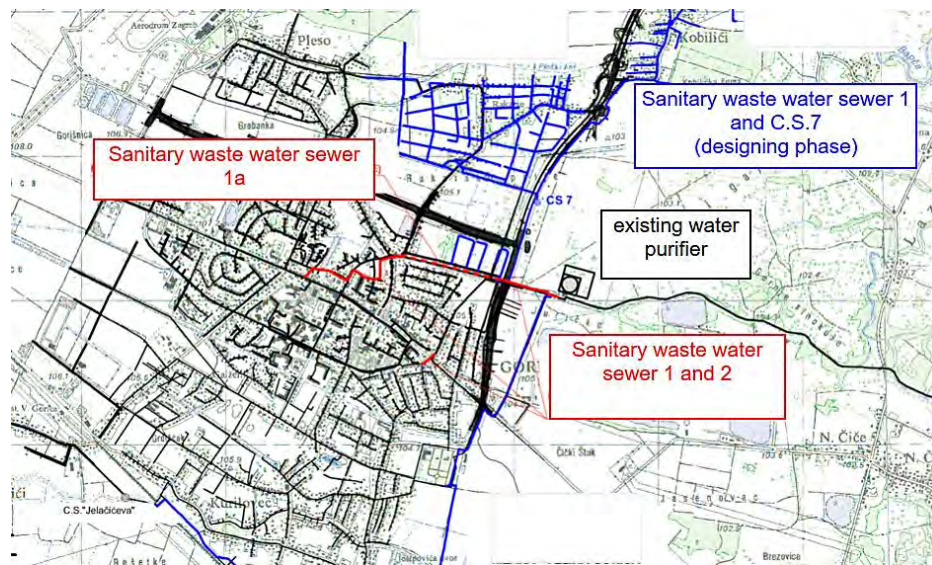
We used the method on other pipeline project from the same sewer system in which we first extracted quantities of work and average production rate for major leading activities and based on these two variables determined activity duration and all other necessary variables for time calculation based on algorithm. We used the algorithm and variables to provide an equation for total project duration and calculated the time of this project based on major leading activities.

## **4. Results and disscusion – method development and verification**

### *4.1. The set of representative activities as main characteristic of linear pipeline project*

With goal of early time estimation for sewer system which contains numerous pipelines organized in LOTS, technical documentation for all projects (pipelines) was analyzed. One project was chosen as a representative, since it had all types of repetitive activities (work groups) that were detected in all other projects. Based on the location, terrain condition, quantities of work and presumed average machinery are determined. Every representative

activity was manually planned (composition of labor and number of labor were set and their performance were determined) and their duration was calculated.



**Figure 5: Representative project on LOT1**

4.2. *The representative activities are:*

1. Pulverizing and grinding of existing roadway
2. Mechanical excavation
3. Manual excavation
4. Replacement of low foundation material
5. Planning and compacting/ Trimming, levelling and grading the landfill base
6. Spreading filter pedestrian finishing base
7. Installation of manholes
8. Lower Pipe into Trench
9. Spreading filter single-size rounded gravel as a protection dam above the pipes
10. Backfill
11. Embankment- Road compacting
12. Base Pavement- Base Course Layer
13. Surface Pavement- Binder and Wearing Course

Every other pipeline project in this sewer system have same or less types of work meaning that these thirteen activities will be the same for other projects or some projects will have less activities which means zero duration for some of these thirteen activities. First activity which consider removing the top layer of ground can be changed in other projects because on some locations there is soil above the pipeline instead of existing roadway.

Nkado (1992) had a same approach in his model where he defined required major types of works and major activities for the construction of new buildings. Duffy (2009) applied the methodology for defining activities comprising majority of the construction effort based on a pipeline project. Many scholars suggest an approach (Peer, 1974; Hamerlink, 2001; Hegazy

and Kamarah, 2008) of developing major activities for linear projects which leads the project duration.

#### 4.3. Detailed linear schedule with major leading activities

Sewer project is characterized by evenly distribution of quantity along a linear path/space (Duffy, 2009). Since sewer projects typify manholes (physically breaking the project into spreads), they were used as stations whereby the quantity would be distributed. By using linear interpolation method, distribution was carried out through project stations for each type of work, e.g. each representative activity. Result is that production rates of the activities are uniformed and constant meaning that all activities are converted to continuous full-span linear activities including manholes which are usually partial-span activity. Duration for every activity was calculated from the quantity assigned to the activity, and information about workgroup production rate information input as shown in the following equation (Halpin and Riggs 1992; Reda 1990).

$$T_a = \frac{Q}{U_p \times n} \quad (3)$$

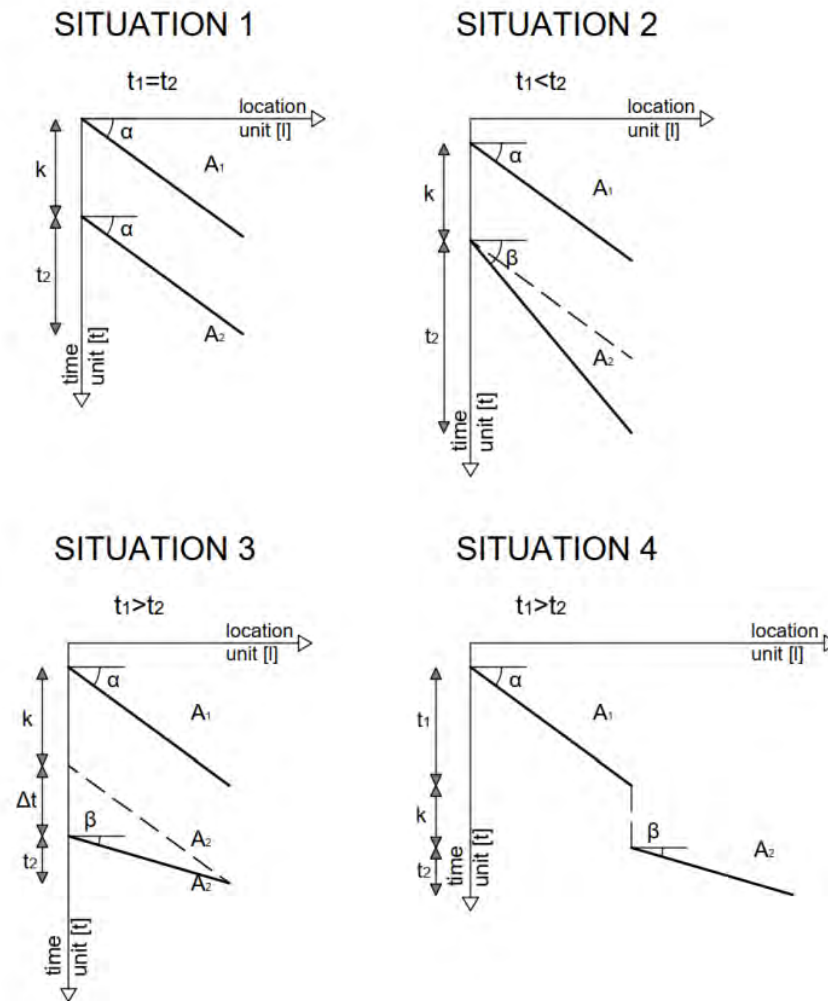
where Q is the quantity of material, divided by the multiplication of the number of workgroups (n), and U<sub>p</sub> the production rate of one work group per day. Su and Lucko (2015) observed production rate of activity as quantity divided by duration meaning that duration is known variable. In this paper focus was on time estimation with known production rate so we considered activity duration (T<sub>a</sub>) as unknown variable. Production rate U<sub>p</sub> of workgroup was calculated manual for each work group (average machinery production rate was considered).

#### 4.4. Defining task links and optimizing the linear schedule

After following hard sequence logic, a masterplan was created which is same method of linear schedule development that Duffy (2009) used in his research meaning that first version of hard-logic plan must be optimized. In optimization process we analyzed LSM made schedule. Depending on the production rate between activities e.g. relationship between slopes of two adjacent activities, appropriate time lags (k) between every two adjacent activities were set with goal to prevent clashes between activities.

The links between two consecutive activities in CPM method are finish-finish, start-start, and finish-start (F-S, S-S, F-F). These different types of activity link from CPM can be related with different relationships of two adjacent activity slopes in LSM plan in the way that based on slope relation one must choose the proper link type. Time lag (k) should be put either on the finish or the start of activity, based on link type, in order to have minimal time buffer y. Time lag (k) is referred to in some papers (Hamerlink 1998, Matilla and Park, 2003) as “least time interval” (LTI).





**Figure 6 Task links and four possible variations between two activities**

When the unit production rate of an observed activity is greater than the unit production rate of the preceding activity the two activities will tend to converge as the number of units' increases. This corresponds to a finish-to-finish (F-F) relationship shown in the equivalent CPM overlapping diagram (figure 4, situation 3) so the time lag ( $k$ ) should be assigned on the finish of the preceding activity. When the production rate of an activity's production line is smaller than the production rate of the preceding activity the activities will tend to diverge as the number of units' increases. This corresponds to a start-to-start (S-S) relationship shown in the equivalent CPM overlapping diagram (Harris and Ioannou, 1998) (figure 4, situation 2) so the time lag should be assigned on the start of preceding activity. Further shortening of the total time schedule with the same labor and production rate of the work group would result in overlapping activities.

#### 4.5. Identifying the key elements in LSM for the development of the total project time algorithm

Construction plan for our pipeline project consists from linear continuous full span activities where project duration can be calculated through equation 2. The main issue for using LSM in early estimation is how to determine time buffer  $y$ . We determined equation for

calculation of the slope of the activity which in LSM is represented as angle between activity and x-axis, (e.g. slope of the activity):

$$\alpha = \tan^{-1}\left(\frac{\Delta Q}{U_p \Delta l}\right), \quad (4)$$

where  $\Delta Q$  represents the quantity,  $U_p$ , production rate of the activity per day and  $\Delta l$ , the station length at which the activity will be executed. It is important to note that all variables in equation 4 are known parameters for all of our leading activities.

<p>SITUATION 1. <math>\alpha = \beta</math></p> <p>PRODUCTION RATE: task A1 and A2 are equal.</p> <p>RECOMMENDED TASK LINK: (S-S)</p> <p>TOTAL DURATION: <math>T = k + t_2</math></p> <p>TIME BUFFER: <math>y = k</math></p>	<p>SITUATION 2. <math>\alpha &lt; \beta</math></p> <p>PRODUCTION RATE: task A1 is faster than A2.</p> <p>RECOMMENDED TASK LINK: (S-S)</p> <p>TOTAL DURATION: <math>T = k + t_2</math></p> <p>TIME BUFFER: <math>y = k</math></p>
<p>SITUATION 3. <math>\alpha &gt; \beta</math></p> <p>PRODUCTION RATE: task A2 is faster than A1.</p> <p>RECOMMENDED TASK LINK: (F-F)</p> <p>TOTAL DURATION:</p> $T = k + t_1 - t_2 + t_2$ <p>TIME BUFFER:</p> $y = k + \Delta t = k + t_1 - t_2$	<p>SITUATION 4</p> <p>PRODUCTION RATE: <math>\alpha &gt; \beta</math>; <math>\alpha &lt; \beta</math>; <math>\alpha = \beta</math></p> <p>RECOMMENDED TASK LINK: (F-F)</p> <p>TOTAL DURATION:</p> $T = t(A_2) + k + t_2$

**Figure 7: The equations for calculation time buffer and duration of adjacent activities**

For four situation explained in previous subchapter, we developed the expression for duration between two adjacent activities and expression for buffer  $y$  which we divided on two parts. Part  $k$  is time lag which must be set to prevent overlap of two adjacent activities and part  $\Delta t$  read on y-axis which is consequence of finish-to-finish link (figure 4, situation 3). Situation 4 is specific for activities which execution is done only on some part of pipeline and those activities should have finish-to-start (F-S) relationship with adjacent activities in order to correspond with situation 4. It could be included in equation of total project duration but in this case study we observed only linear continuous full-span activities. Necessity for developing expressions shown in figure 5 (e.g. situations from 1 to 4) is in nature of LSM schedule and related equation 2 where buffer  $y$  is located and read on y-axis. With expressions provided in figure 5 we can amend equation 2 for calculation of project duration and develop algorithm which will provide the way to properly develop minimum buffer time  $y$  (as it would be in optimized linear schedule) and calculate the total project duration without need to develop linear schedule.

4.6. Developing the variables and the algorithm for base time estimation of linear construction project

As we already stated for every representative activity quantity (Q) and production rate (Up) is known and for continuous full-span activities length (Δl) is the same. Based on these three variables the remaining variables can be determined using equations and expressions presented in aforementioned subchapters and they these variables are shown in table 1.

**Table 11: Representative activities of the pipeline project examined in case study**

		Variables determined from BoQ								
	REPRESENTATIVE ACTIVITIES	ΔQ	U <sub>p</sub>	Δl	t <sub>n</sub>	α,β	TASK LINK	k	y	
1	Pulverizing and grinding of existing roadway asphalt or concrete curtain	2662,807	292,08	920	10	0.009909	F-F	1	6	
2	Mechanical excavation	2949,962	669,76	920	5	0.004787	F-F	1	4	
3	Manual excavation	737,49	669,76	920	2	0.001199	F-F	0	1	
4	Replacement of low foundation material	474,896	878,40	920	1	0.000588	S-S	1	1	
5	Trimming, levelling and grading the landfill base	1637,047	2927,9	920	1	0.000608	F-F	1	1	
6	Spreading filter pedestrian finishing base	248,39	878,40	920	1	0.00030	S-S	1	1	
7	Installation of manholes	47	2,00	920	24	0.012771	S-S	0	0	
8	Lower Pipe into Trench	849,38	36,40	920	24	0.025358	F-F	1	23	
9	Spreading rounded gravel above the pipes	1273,79	878,40	920	2	0.001576	S-S	1	1	
10	Backfill	2815,45	1152,9	920	3	0.002654	F-F	1	3	
11	Embankment- Road compacting	941,31	1112,6	920	1	0.000920	S-S	1	1	
12	Base Pavement- Base Course Layer	2344,797	1145,4	920	3	0.002225	S-S	1	1	
13	Surface Pavement- Binder and Wearing Course	2344,797	1145,4	920	3	0.002225				
Total time									46	

Following the equation (2) and expressions from figure 5, with known activity duration and determined time buffer y, the total duration of project is:

$$T_t = t_{cut} + k - t_{Mechanical} + t_{Mechanical} - t_{Manual} + t_{Manual} + k + k + k + k + k + t_{Installation} + k - t_{Rounded\ gravel} + k + t_{Backfill} + k - t_{Surfacing} + k + k + t_{Surface} \quad (6)$$

$T_t$  =total time

$k$  =time lag

$t_n$  =duration of activity projected on time axis

$$T_t = 10 + 1 - 5 + 5 + 0 - 2 + 2 + 1 + 1 + 1 + 0 + 1 + 24 + 1 - 3 + 1 + 4 + 1 - 2 + 1 + 1 + 3 = 46$$

In order to define buffer time ( $y$ ) and determine total project time we amend the equation 2 and developed algorithm which is presented in equation 7 and corresponding mathematical expressions:

$$T_t = \sum_1^{n-1} y + t_n \quad (7)$$

$t_n$  = duration of the last activity

$\sum y$  = represents the sum of all time buffers

Time buffer is determined by the conditions:

$$\alpha \leq \beta, y = k;$$

$$\alpha > \beta, y = k + \Delta t = k + t_1 - t_2 = k + \frac{Q_1}{U_{p1}} - \frac{Q_2}{U_{p2}}$$

$$\alpha = \tan^{-1}\left(\frac{\Delta Q_1}{U_{p1} \Delta l}\right); \beta = \tan^{-1}\left(\frac{\Delta Q_2}{U_{p2} \Delta l}\right) \text{ on station } \Delta l$$

$\alpha$  production rate of the precedence activity

$\beta$  production rate of the succeeded activity

This algorithm provides us with an easy way to determine proper and accurate buffer time of all construction project activities without the need to develop detail linear schedule and read the buffer time ( $y$ ) from time axis ( $y$ -axis) and this is shown in table 1. Based on activity buffers equation for total project time can be easily developed, which is shown in equation 6. With presented algorithm one only need to know basic activity variables ( $Q, U_p, \Delta l$ ) which can be determined in preliminary phase based on technical documentation while with formerly mentioned equation 2 project duration couldn't be calculated unless detail linear schedule was developed and graphically represented.

#### 4.7. Verification of the developed method

Representative activities and their quantities of work can be determined from the technical documentation and number of location splits can be determined based on location of manholes. For every activity average production rate of workgroup can be determined from former projects or standardized norms for production rate of construction operations. Based on these variables it is possible to define every other variable needed to calculate the project duration (table 1). There is no need to develop linear schedule and therefore this can be used as rapid way to provide early base time estimation on other linear projects with continuous linear full-span activities. In sewer system observed in our case study we picked other pipeline project and assumed same production rate and working crews as in pipeline projects presented in table 1 and easily determined project duration based on developed method.

## 5. Conclusion

In this paper we presented the state of the art of early time estimation models and we found a small amount of these models with low evidence of their usage especially for linear projects with repetitive activities. We describe state of the art of project planning and scheduling of projects with repetitive activities such as roads and pipelines. Linear scheduling method (LSM) was found as the most useful for planning of these type of projects. To be able to exploit benefits of LSM for early time estimation we developed method for early time estimation for project with linear repetitive activities. Main features of this method can be described through three simple steps; first step is to determine project major leading activities, second to calculate all important variables of this activities based on two known variables (quantity of work and production rate) and third is use the developed algorithm and make a calculation of project duration. We explained process of method development and how it can be used.

First limitation is that presented method can serve only for base estimation because it includes only major construction activities without risk and uncertainties included in estimation. The accuracy of base time estimation is not tested, since the method has not yet been used for early estimation on real projects. Despite these limitations this method can help practitioners and scholars to easily calculate the project duration and to relate project quantities of work and average production rates of work groups with total project duration. In process of verification we showed that this method enables rapid way for early base time estimation of linear projects. Different variants of work groups and production rates can be tested in simple manner and thus method can contribute to construction project management related tasks e.g controlling the speed of contractor works on site activities and equipment utilization versus contract plan. Algorithm and method developed in this paper represents a basis for creating a base estimation model for early time estimation of linear (infrastructure) projects oriented on a set of activities.

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# Managing Health and Safety on Construction Sites

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## Abstract:

The South African construction industry continues to generate fatalities, injuries, and disease, and is often non-compliant in terms of H&S. The aim of the study reported on was to determine current and ideal H&S practices relative to managing hazards and risks on construction sites. A survey was conducted among general contractor (GC) members of the East Cape Master Builders Association (ECMBA), and the members and employees of members of the Eastern Cape Institute of Architects (ECIA). The findings of the survey indicate that: H&S is important; H&S practitioners have the greatest influence on H&S; leading, followed by controlling, is the most important management function in terms of managing H&S hazards and risk; the supply of personal protective equipment (PPE) is the most frequent H&S intervention; training with respect to the use and wearing of PPE is the most frequent type of H&S training; communication is a pre-requisite for managing hazards and risks; inadequate H&S training and inadequate commitment to H&S contribute to a poor H&S culture, and a poor H&S culture predominates in terms of the cause of hazards and risks on sites. The conclusions arising from the survey include: respondents perpetuate the industry paradigm of ‘cost, quality, and time vis-à-vis H&S; managing construction H&S is a multi-stakeholder issue; H&S is an integral part of construction management; the focus is on the lower end of the ‘hierarchy of prevention’ in terms of mitigating hazards and risk, and a range of interventions are required to manage H&S effectively.

*Keywords: construction; hazards; health and safety; risk*

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## 1. Introduction

According to Alli (2008), measures and methods for the elimination of occupational injuries and accidents already exist and could be effective if implemented. “Many industrial countries have extensive and comprehensive systems of occupational safety and health (OSH) management, and this is demonstrated by consistently reduced accident rates.” (Alli, 2008)

There have been numerous studies conducted with respect to the accidents which occur in the construction industry, and the findings of these studies have been published. The information from these findings has revealed the extent and patterns of accidents that occur. However, although most of the investigations have focused on the occurrence of the events and the immediate influences; limited research has been conducted relative to the range of contributory managerial, site, and individual factors (Haslam, Hide, Gibb, Gyi, Pavitt, Atkinson, & Duff, 2005). Rasmussen (1997) cited in Haslam et al. (2005) argues the need for an approach that recognises all the contributing factors to organisational and individual behaviour and dynamic work context, as opposed to merely focusing on the errors committed when undertaking tasks and acts.



According to Holt (2001), the causes of accidents can be divided into two categories, namely primary and secondary causes. The primary causes refer to the unsafe acts and conditions, and the secondary to the failure of the management system to anticipate. This includes lack of training, maintenance, adequate job planning and instruction, and not having H&S systems of work in place. He urges the need for the consideration of secondary causes, but states that they are harder to seek out and identify.

It has become apparent that consideration and management of the physical aspects are not enough to reduce accidents. Construction organisations need to address the organisational, managerial and human contributions as well (Mohamed, 2003: 80).

Given the abovementioned a study was conducted, the aim being to determine current and ideal H&S practices relative to managing hazards and risks on construction sites, the objectives being to determine the:

- Importance of six project parameters;
- Extent of influence of various parties on H&S;
- Importance of management functions in terms of managing H&S hazards and risk;
- Frequency of H&S-related actions;
- Frequency of H&S training;
- Importance / Impact of H&S practices on H&S performance, and
- Extent factors contribute to the existence of H&S hazards and risks on construction sites.

## **2. Review of Literature**

### *2.1. Introduction*

The review of the literature has been presented relative to a range of issues that relate to the aim and objectives of the study.

### *2.2. The impact of H&S training on H&S awareness*

Provision for employee awareness and H&S in the workplace is a requirement for employers, however, according to Tam and Fung (2008), many workers are unaware of the potential hazards to which they are exposed in their working environments, and as a result, they become susceptible to injury.

Leiter, Zanaletti and Argentero (2009) state that perspective is critical in the work setting, as it has an influence on accident rates. When employees attempt to acquire knowledge and understanding of their work environment through contemplation, experience, and comprehension, there is always a possibility of not complying with safe working practices. There are factors that contribute to an inaccurate evaluation of existing harmful hazards such as experience of an injury at work, and the quality of H&S training (Leiter, Zanaletti & Argentero, 2009).

The workers need to be made aware of the fact that accidents are not unavoidable and that they are caused. They require training to improve the ability to recognise the importance of compliance, adopt safe work systems, and be proactive in correcting unsafe practices (Holt,

2001). Provision of H&S information is not training, and should not be used as a replacement. It is a mistake to make any assumption related to an employee's past experiences and the ability to comprehend information. Furthermore, H&S awareness is a result of training (Holt, 2001).

According to Smallwood and Haupt (2005), H&S education and training play a major role with respect to ensuring the attainment of sufficient levels of awareness. In turn, awareness is a key component for the achievement of an optimum H&S culture.

Since designers effectively influence H&S, they ought to be aware of this influence and be prepared to make valuable contributions. However, the necessary tertiary education, which should include H&S development, is a prerequisite for such awareness and contributions (Smallwood & Haupt, 2005).

### *2.3. Worker use of Personal Protective Equipment (PPE)*

The Occupational Health and Safety Act, No. 85, 1993 (Republic of South Africa, 1993) requires every employee at work to "...carry out any lawful order given to him, and obey the health and safety rules and procedures laid down by his employer or by anyone authorised thereto by his employer, in the interest of health or safety." It is the employer's obligation to provide workers with appropriate H&S gear, as it is important to ensure that they begin work with PPE (Coble, Hinze & Haupt, and 2000).

Regardless of statutory requirements imposed on construction sites, most construction workers are unwilling to use PPE (Tam, & Fung, 2008). PPE should be worn in order to minimise exposure to an array of hazards (Schaufelberger & Lin, 2014).

According to Hughes and Ferrett (2011), PPE does not eliminate the hazard, and if the equipment fails, it can potentially present the wearer with maximum health risks. Hence, as a control measure it should be used as a last resort. They further state that sound supervision and enforcement, the availability of the correct equipment at all times, and effective user training are the components on which the successful use of PPE depends. Holt (2001) also states that it is not acceptable to rely solely on PPE for risk control. Besides the fact that no PPE is 100% effective all the time, it is also not always possible to provide everyone who is in danger, with PPE, as this requires identification of everyone who is at risk first.

This argument is further supported by Tam and Fung (2008) who clearly state that PPE can only be effective if the equipment selected emanates from its intended use, employees are trained in its proper use, and the equipment is properly tested, maintained, and worn.

### *2.4. The impact of H&S training on the H&S culture*

A study conducted by various researchers (Christian, Bradley, Wallace, and Burke 2009 cited in Frazier et al., 2013) determined that providing workers with H&S training has a positive impact on the H&S culture, as it provides them with the related knowledge, which also increases worker motivation. The frequency and quality of H&S training provided by an organisation shows the organisation's commitment to H&S.

H&S education and training play a major role in terms of communicating the importance of H&S and act to improve the manner in which H&S is viewed with respect to its value and also the level of consideration it receives (Smallwood & Haupt, 2005). An H&S culture that pervades in a construction organisation ensures successful safe working. An H&S culture

cannot be manufactured, but requires the time for it to manifest naturally. The advantage of this is that workers in the firm do not simply comply with the H&S rules and regulations, but preferably end up internalising the need for safe working (Fellows, Langford, Newcombe & Urry, 2009).

H&S education and training is required for designers in order to equip them with the required knowledge and skill which are prerequisites for assisting the client with the preparation and provision of H&S specifications and the provision of information that may affect H&S (Smallwood & Haupt, 2005).

According to Cooper (2000), defining the product of H&S culture is very important to clarify what an H&S culture should look like in an organisation. He adds that this also could help to determine the functional strategies required to developing this product, and it could provide an outcome measure to assess the degree to which organisations might or might not possess a good H&S culture.

Haslam et al. (2005) argue that individuals with a poor understanding of learning and skill acquisition, who are given the platform to conduct H&S training in the form of site induction and toolbox talks, promote unsuccessful training which results in the propagation and perpetuation of unfavourable habits instigated by workers learning 'on the job'.

#### *2.5. The poor H&S culture and H&S commitment*

According to OSHA (2003) cited in Frazier et al. (2013), organisations need to view H&S as an investment in order to achieve success. The intermediate costs do not compare to the rectification costs that can be incurred at a later stage. It is critical for H&S cultures to include detection and prevention programmes; these will ensure that costs relating to injuries are reduced while employee awareness increases (Behm, Veltri & Kleinsorge, 2004 cited in Zohar, 2010).

Dollard and Bakker (2010) cited in Frazier et al. (2013), argue the importance of top management communicating and displaying the importance of H&S in order to ensure that positive H&S values pervade an organisation. The leadership should have the same involvement on the field as a football coach on the touchline (Dollard & Bakker, 2010 cited in Frazier et al., 2013).

Management should view H&S behaviour and operation goals as mutually inclusive as prioritising production over H&S encourages unsafe behaviour and a repetition thereof (Frazier et al., 2013). Smallwood and Haupt (2005) advocate 'zero accidents' as a goal for any organisation striving to ensure an optimum H&S culture, stating belief as the ultimate requirement for the attainment of such a goal. The goal of zero accidents requires the utmost commitment from the top down.

An organisation's existing H&S performance is thought to influence workers' attitudes and behaviour given that H&S culture is a sub-facet of organisational culture (Cooper, 2000). The views of the employees with respect to what and how things should be executed, along with all kinds of conduct that get attention, are what make up an organisational climate (Schneider, 1990 cited in Zohar, 2010).

According to Geller (2001a) cited in Frazier et al. (2013), a positive H&S culture is vital in terms of ensuring the united efforts of management and employees in ensuring a healthy and

safe workplace. The importance of H&S is an issue that should be continuously communicated by management. Furthermore, organisations should provide proper equipment along with appropriate H&S procedures for the employees (Frazier et al., 2013).

## 2.6. *Ineffective communication*

A study conducted by Olanrewaju et al. (2017) determined that primarily, the misinterpretation of instructions leads to poor communication on sites. Similarly, workers that demonstrate poor communication skills are unable to express themselves, which can cause problems onsite. Workers onsite who are not familiar with the signs and symbols used are at a greater risk of performing the tasks incorrectly. The lack of formal education for most workers leads to their learning about construction activities onsite. This results in poor communication styles, gestures and choice of words (Olanrewaju et al., 2017).

Jablin and Putnam (2001) cited in Conrad (2014) argue that from the perspective of employees, there is a human desire to be heard and for their ideas to be respected. Therefore, it is vital for managers to possess good listening skills in order to encourage all employees to identify and solve work-related problems. Conrad (2014) in turn argues that poor communication is the cause of most work-related problems - either incorrect or incomplete communication.

Oral communication is the most preferred form of communication on construction sites, and is the most frequently used. However, it contributes substantially to communication breakdown (Kerzner, 1992 cited in Smallwood & Venter, 2002). One of the major barriers to the success of H&S management is the inability for every person in a construction project to communicate in one common language (Bibb & Bust, 2006). The transfer of information is a critical component of H&S management, but faces the challenges of high levels of illiteracy among the workers (Bibb & Bust, 2006).

Conrad (2014) states that communication is the stimulus of an organisation and without it, matters will deteriorate. According to Drucker (1954) cited in Conrad (2014), there are five functions of management which are dependent on communication, namely controlling, leading, organising, planning, and staffing. Unfortunately, organisations and employees often lack the ability to learn and utilise good communication practices.

## **3. Research**

### 3.1. *Research method and sample strata*

The quantitative research method was adopted, and a self-administered questionnaire survey was conducted. The sample consisted of 70 GC members of the ECMBA, and the 35 members and employees of members of the ECIA in Port Elizabeth. The questionnaire consisted of 16 questions, most of which were five-point Likert scale type questions. The questionnaires were distributed via e-mail and per hand. A total of 29 questionnaires were returned, which included 18 GC and 11 ECIA responses, which equates to response rates of 26% and 31% respectively, and an overall response rate of 28%.

Limitations of the study include that only two stakeholder groups were included, and then the study was localised in terms of the City of Port Elizabeth.

### 3.2. *Research findings*

Table 1 presents a comparison of the responses of the architects and GCs with respect to the importance of six project parameters to their organisations. It is notable that all the mean MSs are greater than 3.00, the midpoint, which indicates that in terms of the mean, the project parameters are more than important, as opposed to less than important.

However, it is notable that all the MSs are  $> 4.20 \leq 5.00$ , which indicates that the parameters can be deemed to be between more than important to very important / very important. Quality predominates, followed by schedule (2<sup>nd</sup>), productivity (3<sup>rd</sup>), H&S (4<sup>th</sup>), cost (5<sup>th</sup>), and environment (6<sup>th</sup>).

Quality is ranked first and second by the architects and the GCs respectively, and H&S is ranked fourth by the architects and first by the GCs. The MSs indicate that H&S is regarded as marginally more important by the GCs (4.89) than by the architects (4.45); it can be argued that this is because H&S accidents occur on site. Furthermore, only 1 / 5 (20%) architects' MSs is greater than the MSs of GC.

Table 1. Importance of six project parameters according to architects and GCs

Parameter	Architects		GCs		Mean	
	MS	Rank	MS	Rank	MS	Rank
Quality	5.00	1	4.89	2	4.93	1
Schedule (Time)	4.73	3	4.83	3	4.79	2
Productivity	4.73	2	4.78	4	4.76	3
H&S	4.45	4	4.89	1	4.72	4
Cost	4.45	3	4.61	5	4.55	5
Environment	4.27	5	4.35	6	4.32	6

Table 2 presents a comparison between the responses of the architects and GCs with respect to the influence of 18 parties forming part of the project team in terms of managing H&S hazards and risks. It is notable that in terms of the mean MS, 14 / 18 (78%) of the MSs are greater than 3.00, the midpoint, which indicates that according to respondents, the parties have more than average as opposed to less than average influence in terms of managing H&S hazards and risks.

According to the architects, H&S agent, H&S manager, and H&S officer are ranked first, second, and third respectively, with respect to their influence in terms of managing H&S hazards and risks. GCs ranked site manager, structural foreman, and H&S officer as first, second, and third respectively, and based on the mean MSs, H&S agent, H&S manager and H&S officer are ranked first and joint second respectively. Furthermore, H&S officer (3<sup>rd</sup>) has a higher MS in the case of GCs than architects, which means that GCs regard it as marginally more important.

The MS range of  $> 4.20 \leq 5.00$  indicates that the influence of the parties is between a near major extent to major / major extent – H&S agent (1<sup>st</sup>), H&S manager (2<sup>nd</sup>), H&S officer (3<sup>rd</sup>), site manager (4<sup>th</sup>), structural foreman (5<sup>th</sup>), H&S representative (6<sup>th</sup>), supervisor (7<sup>th</sup>), team leader (8<sup>th</sup>), contracts manager (9<sup>th</sup>), and construction project manager (10<sup>th</sup>). MSs  $> 3.40 \leq 4.20$  indicate that the influence is between some extent to a near major / near major extent – workers (11<sup>th</sup>), and client (12<sup>th</sup>). MSs  $> 2.60 \leq 3.40$  indicate that the influence is between a near minor extent to some extent / some extent - structural engineers (13<sup>th</sup>), civil engineers (14<sup>th</sup>),

architectural designers (15<sup>th</sup>), materials manager (16<sup>th</sup>), contractor's QS (17<sup>th</sup>), and consultant / client QS (18<sup>th</sup>).

It is notable that 7 / 18 (39%) architects' MSs are greater than the MSs of the GCs. The party that reflects the biggest MS difference between the architects and GCs is the client with a difference of 1.18. The difference is significant as the architects' MS is in the range of  $> 2.60 \leq 3.40$ , which indicates influence between a near minor extent to some extent / some extent, and the GCs' MS is in the range of  $> 3.40 \leq 4.20$  an influence between some extent to a near major / near major extent.

Table 2. The extent of influence of various parties according to architects and GCs

Party	Architects		GCs		Mean	
	MS	Rank	MS	Rank	MS	Rank
H&S Agent	4.91	1	4.83	5	4.86	1
H&S Manager	4.82	2	4.83	6	4.83	2
H&S Officer	4.73	3	4.89	3	4.83	3
Site manager	4.64	5	4.89	1	4.79	4
Structural foreman	4.64	6	4.89	2	4.79	5
H&S Representative	4.73	4	4.78	8	4.76	6
Supervisor	4.55	7	4.83	7	4.72	7
Team leader	4.09	9	4.78	9	4.52	8
Contracts manager	3.90	10	4.83	4	4.50	9
Construction project managers	4.36	8	4.17	11	4.24	10
Workers	3.73	11	4.33	10	4.10	11
Client	2.82	17	4.00	12	3.55	12
Structural engineers	3.36	12	3.33	13	3.34	13
Civil engineers	3.27	13	3.06	14	3.14	14
Architectural designers	3.18	14	2.83	16	2.97	15
Materials manager	2.82	18	2.94	15	2.90	16
Contractor's QS	3.00	15	2.67	17	2.79	17
Consultant / Client QS	2.91	16	2.33	18	2.55	18

Table 3 presents a comparison between the responses of the architects and GCs with respect to the importance of five management functions in terms of managing H&S hazards and risks. It is notable that all the mean MSs are greater than 3.00, the midpoint, which indicates that the respondents consider the project parameters as more than important, as opposed to less than important.

According to the architects, coordination, leading, and controlling are ranked first, second, and third respectively, in terms of managing H&S hazards and risks. GCs ranked leading, controlling, and planning as first, second, and third respectively. In terms of the mean MSs, leading, controlling, and coordination are ranked first, second, and third respectively.

The MS range of  $> 4.20 \leq 5.00$  indicates that the importance is between a near major to major / major importance – leading (1<sup>st</sup>), controlling (2<sup>nd</sup>), coordination (3<sup>rd</sup>), planning (4<sup>th</sup>), and organising (5<sup>th</sup>). It is notable that all the MSs of the architects are less than the MSs of the GCs. The management function with the biggest MS difference is planning with a difference of 0.74. There is a notable difference as the architects' MS is in the range of  $> 3.40 \leq 4.20$ , between importance to near major / near major importance and the GCs' MS is in the range of  $> 4.20 \leq 5.00$ , which indicates that the importance is between near major importance to major / major importance.

Table 3. The importance of management functions in terms of managing H&S hazards and risk according to architects and GCs

Function	Architects		GCs		Mean	
	MS	Rank	MS	Rank	MS	Rank
Leading	4.27	2	4.94	1	4.68	1
Controlling	4.27	3	4.71	2	4.54	2
Coordinating	4.36	1	4.59	4	4.50	3
Planning	3.91	5	4.65	3	4.36	4
Organising	3.91	4	4.53	5	4.29	5

Table 4 presents a comparison of the frequency at which actions are performed by the architects' and GC organisations on site in terms of managing H&S hazards and risks. It is notable that in terms of the mean MS, except for one, all the MSs are above 3.00, the midpoint, which indicates that the respondents consider the actions to be performed frequently, as opposed to infrequently.

The MS range  $> 3.40$  to  $\leq 4.20$  indicates that the frequency at which the actions are performed is between sometimes to often / often - supply PPE (1<sup>st</sup>), ensure guardrails to elevated platforms (2<sup>nd</sup>), inspect the area of operation before commencing (3<sup>rd</sup>), confirm certification of any temporary structure before operating (4<sup>th</sup>), identify and use designated waste containers (5<sup>th</sup>), identify emergency exits (6<sup>th</sup>), identify safe access routes (7<sup>th</sup>), H&S induction (8<sup>th</sup>), clean work areas after completion of a task (9<sup>th</sup>), conduct HIRAs (10<sup>th</sup>), toolbox talks (11<sup>th</sup>), make use of task checklists (12<sup>th</sup>), refer to SWPs (13<sup>th</sup>), check whether hazardous substances will be used for a task (14<sup>th</sup>), refer to method statements (15<sup>th</sup>), and inspect tools and equipment before use (16<sup>th</sup>). The MS range  $> 2.60$  to  $\leq 3.40$  indicates a frequency of between rarely to sometimes / sometimes - check the maximum operation capacity of tools and equipment used (17<sup>th</sup>), and read equipment manuals (18<sup>th</sup>).

It is notable that all the architects' MSs are less than the MSs of the GCs. The action performed with the biggest MS difference is relative to toolbox talks, namely 3.08. The difference is significant as the architects' MS is in the range of  $\geq 1.00$  to  $\leq 1.80$ , which indicates never to rarely and the GCs' MS is in the range of  $> 4.20$  to  $\leq 5.00$  - between often to always / always. The magnitude of the MS difference suggests that these actions are perceived as more onsite related.

Table 5 presents a comparison between the frequency at which GCs and architects' organisations provide H&S training for their employees. It is notable that in terms of the mean MS, all the MSs are greater than 3.00, the midpoint, which indicates that the respondents consider the training as frequent as opposed to infrequent.

The MS range  $> 3.40$  to  $\leq 4.20$  indicates that the frequency at which the training is provided is between sometimes to often / often - the use and wearing of PPE (1<sup>st</sup>), healthy and safe use of tools and equipment (2<sup>nd</sup>), and HIRA (3<sup>rd</sup>). The MS range  $> 2.60$  to  $\leq 3.40$  indicates the frequency is between rarely to sometimes / sometimes - DSTI (4<sup>th</sup>), and emergency procedures (5<sup>th</sup>).

It is notable that the use and wearing of PPE is ranked first by both the architects and the GCs, with a higher MS relative to GCs (5.00) compared to architects (2.45). Furthermore, all the architects' MSs are less than the MSs of the GCs, the biggest MS difference of 3.38 being

Table 4. The frequency of H&S-related actions by GCs and architectural practices on site

Action	Architects		GCs		Mean	
	MS	Rank	MS	Rank	MS	Rank
Supply PPE	3.18	1	4.78	3	4.17	1
Ensure guardrails to elevated platforms	2.78	7	4.72	4	4.07	2
Inspect the area of operation before commencing	3.00	2	4.61	7	4.00	3
Confirm certification of any temporary structure before operating	2.80	5	4.67	5	4.00	4
Identify and use designated waste containers	2.91	3	4.56	9	3.93	5
Identify emergency exits	2.82	4	4.56	8	3.90	6
Identify safe access routes	2.60	8	4.61	6	3.89	7
H&S induction	2.45	11	4.82	2	3.89	8
Clean work areas after completion of a task	2.80	6	4.44	12	3.86	9
Conduct HIRAs	2.22	13	4.50	10	3.74	10
Toolbox talks	1.80	17	4.88	1	3.74	11
Make use of task checklists	2.45	10	4.50	11	3.72	12
Refer to safe work procedures (SWPs)	2.55	9	4.41	14	3.68	13
Check whether hazardous substances will be used for a task	2.10	14	4.44	13	3.61	14
Refer to method statements	2.40	12	4.24	16	3.56	15
Inspect tools and equipment before use	1.90	16	4.33	15	3.46	16
Check the maximum operation capacity of tools and equipment used	1.67	18	3.82	17	3.08	17
Read equipment manuals	2.00	15	3.47	18	2.96	18

relative to DSTI. The difference is significant as the architects' MS is in the range  $> 1.80$  to  $\leq 2.60$  - between never to rarely / rarely, and the GCs' MS is in the range  $> 4.20$  to  $\leq 5.00$  - between often to always / always.

Table 5. The frequency of H&S training according to architects and GCs

Training	Architects		GCs		Mean	
	MS	Rank	MS	Rank	MS	Rank
The use and wearing of PPE	2.45	1	5.00	1	4.03	1
Healthy and safe use of tools and equipment	1.55	3	4.67	2	3.48	2
HIRA	1.64	2	4.56	3	3.45	3
DSTI	1.18	5	4.56	4	3.28	4
Emergency procedures	1.45	4	4.28	5	3.21	5

Table 6 presents a comparison of the extent to which the architects and GCs agree / disagree with statements relating to the importance / impact of H&S practices on a scale of 1 (strongly disagree) to 5 (strongly agree), and a MS with a minimum value of 1.00 and a maximum value of 5.00. It is notable that in terms of the mean MS, all the MSs are greater than 3.00, the midpoint, which indicates that the respondents agree, as opposed to disagree with the statements.



The MS range  $> 4.20$  to  $\leq 5.00$  indicates the concurrence is between agree to strongly agree / strongly agree – communication is a pre-requisite for managing hazards and risks (1<sup>st</sup>), effective H&S hazards and risks management is attributable to a positive H&S culture (2<sup>nd</sup>), inadequate H&S training contributes to a poor H&S culture (3<sup>rd</sup>), inadequate commitment to H&S contributes to a poor H&S culture (4<sup>th</sup>), ineffective communication is attributable to communication barriers (5<sup>th</sup>), and effective HIRA can mitigate hazards and risks (6<sup>th</sup>). The MS range of  $> 3.40$  to  $\leq 4.20$ , indicates the concurrence is between neutral to agree / agree - communicating in workers’ home language is essential for H&S (7<sup>th</sup>), lack of H&S awareness is attributable to inadequate H&S training (8<sup>th</sup>), and workers do not wear PPE as it is perceived as a hindrance (9<sup>th</sup>).

It is notable that 4 / 9 (44%) architects’ MSs are greater than the MSs of the GCs. The statement with the biggest MS difference is ‘Workers do not wear PPE as it is perceived as a hindrance’ with a difference of 1.06. The difference is notable as the architects’ MS is in the range of  $> 2.60 \leq 3.40$  - between disagree to neutral / neutral and the GCs MS is in the range of  $> 3.40$  to  $\leq 4.20$  - between neutral to agree / agree.

Table 6. The extent to which architects and GCs agree / disagree with statements relating to the importance / impact of H&S practices

Statement	Architects		GCs		Mean	
	MS	Rank	MS	Rank	MS	Rank
Communication is a pre-requisite for managing hazards and risks	4.45	2	4.78	1	4.66	1
Effective H&S hazards and risks management is attributable to a positive H&S culture	4.45	4	4.61	2	4.55	2
Inadequate H&S training contributes to a poor H&S culture	4.55	1	4.50	3	4.52	3
Inadequate commitment to H&S contributes to a poor H&S culture	4.45	5	4.41	4	4.43	4
Ineffective communication is attributable to communication barriers	4.45	3	4.39	5	4.41	5
Effective HIRA can mitigate hazards and risks	4.27	6	4.39	6	4.34	6
Communicating in workers’ home language is essential for H&S	4.00	8	4.29	7	4.19	7
Lack of H&S awareness is attributable to inadequate H&S training	4.00	7	3.89	9	3.93	8
Workers do not wear PPE as it is perceived as a hindrance	3.00	9	4.06	8	3.70	9

**Error! Reference source not found.** presents a comparison between the responses of the architects and GCs with respect to the contribution of 16 factors to the existence of H&S hazards and risks on construction sites. It is notable that all the mean MSs are greater than 3.00, the midpoint, which indicates that the respondents consider the factors to make a greater than a lesser contribution.

It is notable that 3 / 16 (19%) architects’ MSs are greater than the MSs of the GCs. The factor with the biggest MS difference is ‘Communication barriers’ with a difference of 0.64. The difference is notable as the architects’ MS is in the range  $> 3.40 \leq 4.20$  - between some contribution to a near major / near major contribution, and the GCs’ MS is in the range  $> 4.20 \leq 5.00$  - between a near major contribution to a major / major contribution.

The MS range  $> 4.20 \leq 5.00$  indicates that the factors make between a near major contribution to a major / major contribution – poor H&S culture (1<sup>st</sup>), non-use of safe working procedures (2<sup>nd</sup>), inadequate H&S training (3<sup>rd</sup>), and inadequate first line supervision (4<sup>th</sup>). The MS range  $> 3.40 \leq 4.20$  indicates between some extent to a near major / near major extent - insufficient task knowledge (5<sup>th</sup>), inadequate worker participation (6<sup>th</sup>), inadequate management commitment (7<sup>th</sup>), communication barriers (8<sup>th</sup>), non-use of PPE (9<sup>th</sup>), job dissatisfaction (10<sup>th</sup>), inadequate HIRA (11<sup>th</sup>), incompetence of management (12<sup>th</sup>), insufficient analytical skills (13<sup>th</sup>), insufficient worker motivation (14<sup>th</sup>), and insufficient toolbox talks (15<sup>th</sup>). The MS range  $> 2.60$  to  $\leq 3.40$  indicates a contribution between a near minor extent to some extent / some extent - design of tools and equipment (16<sup>th</sup>).

It is notable that 3 / 16 (19%) architects' MSs are greater than the MSs of the GCs. The factor with the biggest MS difference is 'Communication barriers' with a difference of 0.64. The difference is notable as the architects' MS is in the range of  $> 3.40 \leq 4.20$  - between some contribution to a near major / near major contribution, and the GCs' MS is in the range of  $> 4.20 \leq 5.00$  - between a near major contribution to a major / major contribution.

Table 7. The extent factors contribute to the existence of H&S hazards and risks on construction sites according to architects and GCs

Factor	Architects		GCs		Mean	
	MS	Rank	MS	Rank	MS	Rank
Poor H&S culture	4.30	2	4.61	1	4.50	1
Non-use of safe working procedures	4.20	4	4.56	2	4.43	2
Inadequate H&S training	4.30	1	4.29	4	4.30	3
Inadequate first line supervision	4.20	3	4.28	5	4.25	4
Insufficient task knowledge	3.70	10	4.33	3	4.11	5
Inadequate worker participation	3.80	9	4.22	7	4.07	6
Inadequate management commitment	4.00	5	4.06	9	4.04	7
Communication barriers	3.60	12	4.24	6	4.00	8
Non-use of PPE	3.80	8	4.06	10	3.96	9
Job dissatisfaction	3.67	11	4.11	8	3.96	10
Inadequate HIRA	3.89	7	3.94	13	3.93	11
Incompetence of management	3.90	6	3.89	14	3.89	12
Insufficient analytical skills	3.40	13	3.94	11	3.75	13
Insufficient worker motivation	3.33	14	3.94	12	3.74	14
Insufficient toolbox talks	3.20	15	3.88	15	3.63	15
Design of tools and equipment	3.20	16	3.06	16	3.12	16

#### 4. Conclusions

Given that two of the three traditional project parameters achieved rankings in the top three in terms of the mean, namely, quality and time, it can be concluded that the respondents perpetuate the industry paradigm of 'cost, quality, and time'. However, it is notable that H&S was ranked first relative to the GCs, and quality first relative to the architects, which leads to the conclusion that 'importance' is stakeholder specific.

In terms of the influence of the project team in terms of managing H&S hazards and risks, it can be concluded that most of the team influence H&S hazards and risk to a major, as opposed to a minor extent. Therefore, managing construction H&S is a multi-stakeholder issue. However, it is notable that in terms of the architects' and mean responses, the three H&S

practitioners are ranked in the top three, whereas in terms of the GCs' responses, site manager (1st), structural foreman (2nd), and H&S officer (3rd), are ranked in the top three, followed by contracts manager (4th). The GCs' responses reinforce the importance of construction management commitment to H&S, and that H&S is an integral part of construction management.

The role of the functions of management work in managing H&S is amplified by the respective responses, and by the degree of importance – between more than important to very / very important. However, notable differences included first ranked leading (MS = 4.94) relative to GCs versus first ranked coordinating (MS = 4.36) relative to architects.

In terms of the frequency of H&S-related actions by GCs and architects on site in terms of managing H&S hazards and risks, it is notable that the architects' practices take the actions less frequently than the GCs, however, this is attributable to them not being directly involved with the physical construction process.

In terms of the frequency at which GCs and architects' practices provide H&S training for their employees, it is notable that the architects' practices take the actions less frequently than the GCs, however, this too is attributable to them not being directly involved with the physical construction process.

The finding that the use and wearing of PPE (MS = 5.00) is ranked first followed by healthy and safe use of tools and equipment (MS = 4.67), and HIRA (MS = 4.56), and DSTI (MS = 4.56) leads to the conclusion that the focus is on the lower end of the 'hierarchy of prevention' in terms of mitigating hazards and risk.

The degree of mean concurrence with statements relating to the importance / impact of H&S practices, and the extent factors contribute to the existence of H&S hazards and risks on construction sites, reinforces many of the previous findings, and leads to the conclusion that to manage H&S effectively requires competent management, management commitment to H&S, optimum H&S training, worker participation in H&S, an optimum H&S culture, optimum supervision, effective communication, constant HIRAs, and following of safe work procedures.

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# Project Management by Modified Gaussian S-Curve

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## Abstract:

Project management within the construction company 'Međimurje graditeljstvo d.o.o', based on past data and standard technology of the company, results in gaining S-curve dispersion. The mathematical definition of the S-curve was dealt with by many scientists such as mathematicians, economists and constructors. 'Međimurje graditeljstvo d.o.o' mainly executes high-rise buildings, and has recently specialized in the construction of structures since they are strong in the formwork and roofing technology. The S-curve designates costs and revenues by means of a cumulative curve during project duration, and in realization enables timely regulation of the execution system. Therefore, in addition to the existing S-curve equations, by using statistical and mathematical methods, a new modified Gaussian S-curve is created in function of cost and time of realization. Nowadays, finance is an important factor in project management because if the financial engineering declines there is no realization of the project. Monitoring the distribution of the existing works on the former projects creates a picture of the company's modeling behavior during project realization. Therefore, the previous projects recognize the company's behavior in the given project conditions using financial indicators. This reduces business risks because by calculating the dispersion of the S-curve distribution, the behavior of the system on future projects can be predicted in relation to the contracted amounts and the agreed project implementation deadlines.

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**Keywords:** *project management, modified gaussian s-curve, business risks, contracted costs and deadlines;*

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## 1. Introduction

The management of a project implemented by a construction industry company is identified with work order management as a code for a specific project. The project monitoring and control system so far has proved to be inadequate, especially for projects with high investment values. Monitoring the project with financial data throughout the facility and per unit of m<sup>3</sup>, m<sup>2</sup>, m', kg and other customizable measures are considered credible, but such experience-based management creates a misleading picture of the progress of the project. Thus, controls, both cost or situational and time variables ones concerning the project, are missing as two key factors in monitoring the status of the project. Therefore, prior project monitoring puts, especially when large investments, high risk projects and even high losses are implied. Today, scientists are interested in monitoring deviations from the plan, ie creating intervals of the range of variations and standard deviations of the observed size. This has created a major precondition for planning precision and reducing business risk.

Thus, the planned cost curve defines the median S-curve out of the performance S-curves. Many scientists have addressed these forecasting problems, and mathematical and statistical formulas for the S-curve have been defined. Statistical data processing has shown that linear

and exponential S-shaped curves exist in productions (Pauše 1988, Vukadinović 1988, Newbold and Carlson and Thorne 2010, Ivković 1980). However, the intentin and aim of the research is to develop more precise, flexible and standardized planning models, ie to more accurately predict the cumulative project curves, ie project situations. The contribution of the representation of the S-curve by the modified Gaussian curve with respect to the existing polynomials is able to define the probabilistic statistics arising from the Gaussian curve as the most common distribution of natural events and thus of construction production.

## 2. Management in Practice and S-curve Methodology

[1] In construction companies at the end of the last century, software technology, i.e. the third industrial revolution, resulted in a comfortable way of managing all data of medium- and giant- sized companies (Lončarić 1995, Vukomanović and Radujković and Alduk 2012) and today, integrated information systems with BIM systems are inevitable (Križaić, 1996, Cui and Hastak and Halpin 2010, Elbeltagi and Hosny and Dawood and Elhakeem 2014). There are various software products in the market and all of them feature both advantages and disadvantages. The process of production planning is the key to managing the project. Microsoft Project has simplified the critical path method to various graphical views. The software is rich in various versions and capabilities, so one expert should make good use of the program to take advantage of all the options. Reports or reports or views in the editor can be great, but then you need to enter every resource with the respective quantitative data, see Figure 1.



Figure 1. MP – gantogram and S-curve (source: author)

The simplest variable to follow for the project-monitoring purpose is money or the S-curve. Various authors have addressed the definition of the S-curve. The given equations from source (Ostojić-Škomrlj and Radujković 2012) are shown in Table 1 and Equation (1).

Table 1. Mathematical scripting of S-curves (source: (Ostojić-Škomrlj and Radujković 2012) )

Autor	Godina	Izraz
Bromilow	1978.	$Y = [ a_0 + a_1(w/t) + a_2(w/t)^2 + a_3(w/t)^3 + a_4(w/t)^4 ] C$
Hudson	1978.	$Y = S [ x + C x^2 - Cx - (6x^3 - 9x^2 + 3x) K ]$
Peer	1982.	$Y = 0,0089 + 0,26981 t + 2,36949 t^2 - 1,39030 t^3$
Tucker	1988.	$Y = \alpha (1 - e^{-(t-d)/\beta})$
Miskawi	1989.	$Y = 3^{1/2} \sin(\pi(1-t)/2) \sin(\pi t) \ln(t+0,5)/(a+t) - 2t^3 + 3t^2$
Boussabain i Elhag	1996.	$za \ 0 \leq x \leq 1/3 \quad Y = 9x^2 / 4$ $za \ 1/3 \leq x \leq 2/3 \quad Y = 3x/2 - 1/4$ $za \ 2/3 \leq x \leq 1 \quad Y = 9x/2 - 9x^2/4 - 5/4$

$$Y_i^{vis.} = -0,0643212823 \cdot x_i - 0,0278540885 \cdot x_i^2 + 0,0016474856 \cdot x_i^3 - 0,000023498997 \cdot x_i^4 + 0,0000001165 \cdot x_i^5 - 0,0000000001 \cdot x_i^6 \quad (1)$$

For given curves, nonlinearity and curvature of the curves are visible, which is in fact a characteristic of the S-curve. The problem is the one-dimensionality of that curve, which is a function of time. The vector observation of a given problem and concentrating the problem on the deviation of the S-curve from the plan and dispersion of variations, initially in time and then in the second- financial -variable, creates spatial S-curves.

### 3. Modified Gaussian S-curve

The assumption is that the plan or realization S-curve can be expressed by means of statistical distribution equations or multi-dimensionally, i.e. through vector 3D methods. To define curves over discrete plan data and to realize project situations, the Gaussian least median of squares method is convenient, see Figure 2.

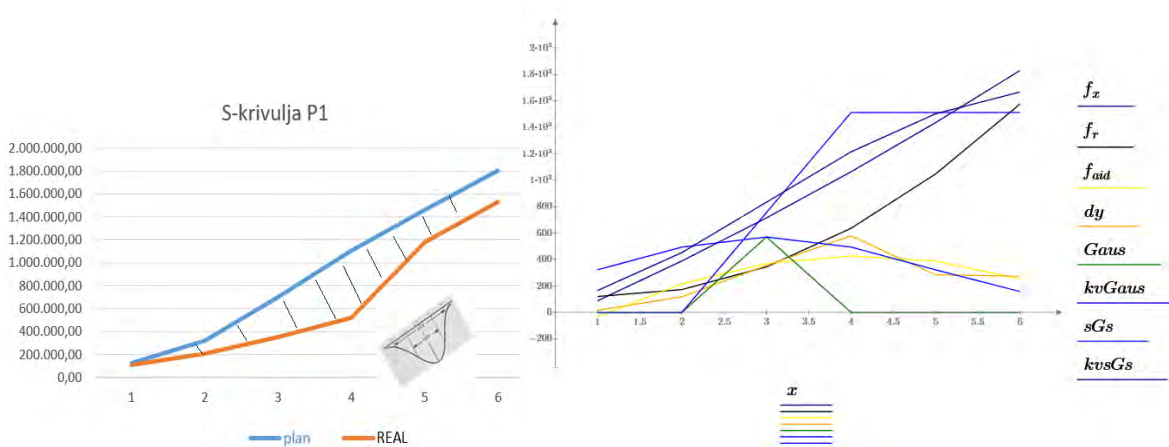


Figure 2. Gaussian dispersion density function of situation realization versus plan

( source: author, data from Međimurje Graditeljstvo 2016)

The S-curves are shown as for:

- fx - planning
- fr - realization
- faid – the difference between polynomials fx-frand vice versa
- dy – discrete discrepancy ( dispersion) – of the plan and actual state
- Gauss – Gaussian density function based on dy
- kvGaus – modified Gaussian density function based on dy
- sGs – cummulative Gaussian function
- kvsGs – cummulative modified Gaussian function

It can be instantly seen from the overview that the dispersion of the realization with respect to the plan with logical distribution , i.e. with approximate Gaussian distribution. It can also be seen that the kvsGs is located between fx and fr; the first sGs curve is fairly interesting, which creates a new idea as an attempt to differentiate the sGs curve from the real ones. Thus, the constant 2 of the Gauss distribution is replaced by the constant kv (2).

$$sGt = \frac{1}{\sigma \cdot \sqrt{2 \cdot \pi}} \cdot e^{-\frac{(x-\mu)^2}{kv \cdot \sigma}} \quad (2)$$

If several projects are observed, the Gaussian results with kv and λkv constants also either deviate from reality or it is not equivalent to reality, see Figure 3.

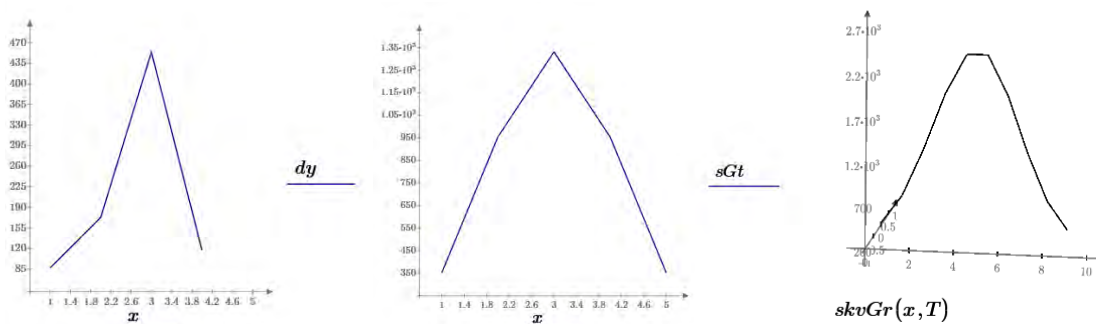


Figure 3. Distribution density function – discrete, Gaussian, modified Gaussian (source: author)

Therefore, modifying the  $\sigma$  Gaussian density function of the data distribution density, first with a constant and using the equation of the direction (3) as a functional connection of  $\sigma$  with T, creates a more precise distribution curve that is almost identical to the discrete data.

$$\sigma = -3.81 \cdot 10^{-8} \cdot T + 7.57 \cdot 10^{-4} \quad (3)$$

Leveling and matching of curves, or modification of the Gaussian curve, refers to the introduction of a constant kv parameter of 10,000 units instead of a constant 2 that multiplies  $\sigma$ . A variable λkv of 0.7 is introduced for projects when the planned exceeds the realized and 3 for the inverse view. All three variables in function are E (t) which represents half of the project. The modified Gaussian S-curve (4) is much more accurate than the first version and the realization curves almost overlap, see Figure 4.



$$skvGr(x, T) = \lambda kv \cdot \int_0^x \frac{1}{(a \cdot T + b) \cdot \sqrt{2 \cdot \pi}} \cdot e^{\frac{-(x-\mu)^2}{kv \cdot (a \cdot T + b)}} dx$$

(4)

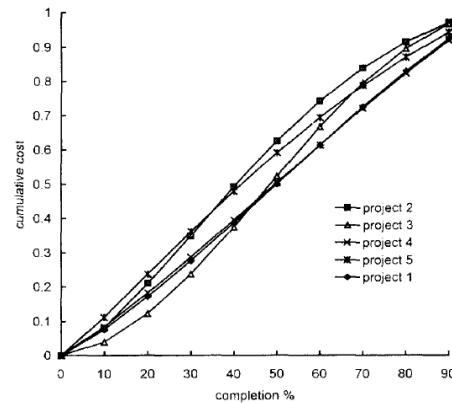
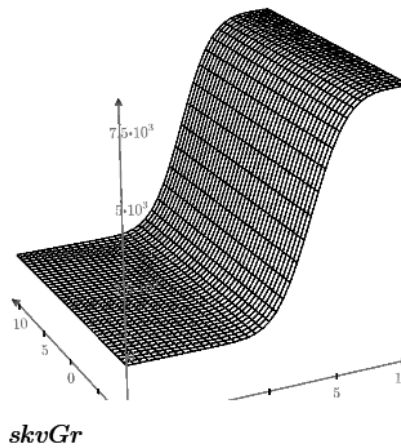


Figure 4 Sample of cost – time curves used in training

Figure 4. Modified Gaussian curve (source: autor and (Kaka and Lewis 1998)

The Gaussian curve modified in that way is a function of two variables,  $x = t$  months of production time and  $z = T$  representing the investment amount whereas the third axis is  $y = n$  representing the project number.

#### 4. Conclusion

Based on some data from the field, namely the data provided by the Medimurje, graditeljstvo company d.o.o. dependency of distribution of realization data with respect to the plan was observed. The dispersion, or scattering, of plan-real difference data has a certain logical form in the form of a statistical Gaussian equation of distribution of random variables as a function of the probability of the event probability difference, that is, the deviation of the realization from the project situation plan (Eun and Kyung 2012). By linking a couple of projects and linking the main variables within the Gaussian equation with field data or construction production situations, a new general definition of the S-curve has been created as a function of production time and project cost or project situation. The given equation is just a prototype for a real S-curve in function of situation, value of costs or income, and time variable of investment duration. More field data is needed to study the linear models that are proposed and to define the coefficients  $a$ ,  $b$ , with as much precision and probability as possible. To determine the true values, the function  $skvGr(x, T)$  is multiplied by 1000 to obtain cost data in millions, as is the case with projects in practice. This will create a more accurate forecast of project planning and deviations, i.e. plan dispersion and implementation will have a roughly identical curves. Defining the general equation of the S curve in a multidimensional space therefore offers the whole set of S curves as the supremum and infimum of the S-curve data set in a project. This in turn creates a probability area using statistical curves, so better risk management in the project is possible, that is, it also enables production management to use the

assumed modified Gaussian S-curve, which opens a new area of research. The limitation of the curve is that it is favorable for the creation of an ideal or optimal curve of the planning S-curve, while for realization it must be complemented with the dispersion of deviation of the realization curve from the planning one. Interestingly, this deviation dispersion is also formed by the Gaussian function of the event probability density distribution (Barraza and Back and Mata 2004).

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# Contractor-Collaborators Logistics System Prototype for Construction Projects

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## Abstract:

High-rise building has taken greater importance in recent years in Chile, with a sustained increase especially in residential projects. This situation has generated greater demands for construction companies regarding project logistics, especially in relation to the planning and coordination between the contractor and its subcontracts, suppliers and distributors. To face this, a study was carried out to develop a prototype of a logistic management system that supports daily work on construction sites. This system reports logistical events to both the contractor project team and the contractor's providers of services and/or supplies, to deliver information in real time about what is currently happening in the project and what is coming in their future stages. To achieve the above, interviews were conducted with professionals in the high-rise building sector to identify the most relevant factors associated with the process, to later develop the prototype. This system was developed using economic elements of easy access for construction companies, being a good option for small and medium companies that cannot make large investments in information technologies. This prototype was implemented in a construction project showing positive results in the logistics planning process, improving communication and coordination between the construction company and its collaborators and generating savings in construction costs. Thus, by applying simple tools that focus on the main weaknesses of the logistics process, it is possible to achieve important changes, opening new possibilities for development in this area.

*Keywords: logistics; high rise building; prototype; logistics planning; communication*

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## 1. Introduction

Logistic planning is the ever-constant process of getting the resources to the right place, at the right time, in a safe manner, and for the least amount of money (Koch, 2015). Having adequate systems to perform this process can lead to savings of 5% of the total value of the construction of a project, by reducing the use of materials for losses, minimizing transportation costs, achieving an early completion of the project by logistics planning, generating less waste and achieving a more stable work flow (Agapiou and Clausen, 1998). Then, the logistic of a jobsite is a major influence on the profitability of a construction project (Koch, 2015). Logistics are related to planning. Unfortunately, regarding this last topic, the industry presents several problems. In Chile, more than 10 years ago, attention was already being drawn to the general low communication on construction projects, which strongly affected the way in which construction works were planned (Corporación de Desarrollo Tecnológico, 2007). The same authors pointed out the importance of a good management of the logistics department, because

of the influence it has in the productivity of projects. A recent document again highlights problems regarding planning, especially at operational planning, where the greatest weaknesses were found in relation to the analysis and management of the problems on site (Corporación de Desarrollo Tecnológico, 2018). This same report recognizes as one of the drivers to face these problems the logistics and the supply of resources, proposing as a good practice the establishment of controls of supplies/materials, equipment and machinery with focus on planning. Regarding information technologies that support the logistics planning process, in Chile there are different commercially available computer programs, which are mainly used for administration and control, but which do not support the processes carried out in the field, such as the delivery, distribution and reception of materials (Mellado, 2015).

To better understand the problem of logistics planning and propose a solution to current problems, the study presented in this article developed a Contractor-Collaborators Logistics System Prototype for construction projects. Given the limited research period (4 months), to define the scope of the study it was determined only to focus on high rise building, since in the last five years there has been an important advance in the execution of this type of projects in the country (Cámara Chilena de la Construcción, 2015). By 2018, residential apartment construction reached almost two-thirds of the total residential construction in Chile (Cámara Chilena de la Construcción, 2018). Also, in the last 15 years most projects have been high rise buildings, with percentage increases ranging from 12.6% to 17.5 % of total housing in the country (Instituto Nacional de Estadísticas, 2017).

This type of project is often faced with problems to meet the deadlines defined in the contract. Among the causes of lost time in high rise building are coordination, supervision, work methodology and the supply of materials (Corporación de Desarrollo Tecnológico, 2013). Thus, given the significant volumes in sales and investment projections for the next few years, there is interest in the area to find improvements that provide benefits in the logistics management processes, since the participation of the logistics area in reference to the budgets of construction projects can reach between 20% to 30% of the project budget.

On the other hand, it should be considered that the construction industry is one of the least digitized industries, next to agriculture and hunting (McKinsey Productivity Sciences Center, 2016). Therefore, it is important to introduce new computerized systems and tools in the sector but given that a large part of the companies that comprise it are small and medium it is necessary to consider some factors. For example, most construction SMEs lack the budget to invest in Information and Communication Technologies (ICT) or have difficulties adopting them (Nuñez *et al.*, 2018). Among the problems faced by these companies are (Dainty *et al.*, 2017): (1) lack of elementary digital experience caused by lack of interest and inclination to use ICTs, and a general unattractiveness of the new technology, (2) no possession or access to the relevant hardware and software, (3) lack of digital skills caused by insufficient user friendliness and lack of education and training, and (4) lack of significant usage opportunities.

Then, the prototype of the Contractor-Collaborators Logistics System was developed using economic elements of easy access for construction companies, being a good option for small and medium companies that cannot make large investments in information technologies. In

addition, it is simple to use, which makes it easier for all critical participants to use it, reducing barriers to its implementation.

In the next section of this article, some definitions regarding logistic and supply chain management are provided, followed by the methodology used in the study. Then, the results obtained from interviews with construction professionals are shown. The following section present the prototype system and the results of its implementation in a construction project. Finally, the main conclusions of the study are presented.

## **2. Logistic and supply chain management**

Logistic is a concept that can be understood in different ways, such as a system of resource flow from the supplier to the customer, as a philosophy of managing the processes of goods and information flows or as the efficient transfer of goods from the source of supply to the points of consumption in a cost-effective way while achieving acceptable level of customer satisfaction (Sabotka and Czarnigowska, 2005; Said and El-Rayes, 2014). In the construction industry few companies have adopted logistics management despite the benefits in cost that it generates, possibly because of the fragmented nature of the industry and the need to integrate and compile large amount of material logistics data (Said and El-Rayes, 2014).

Logistics is an activity within the supply chain. Supply chain management aligns upstream and downstream companies to create value for the customer, regulating the material, information and cash flows among a group of aligned companies (Dallasega *et al.*, 2018). The planning and management of supply chains require properly specifying the participating members and identifying the relationships among them (Cheng *et al.*, 2010). In the construction, the supply chain involves different actors that have different distances to the location of production, affecting the resulting planning (Dallasega *et al.*, 2018).

Among construction supply chain activities, material/component procurement is one of the most demanding tasks, as materials are consumed in large quantities and need to be delivered to a specific location (Jáskowski *et al.*, 2018). Also, the cost of materials can constitute 50% to 60% of the total cost of a construction project, therefore its efficient management is essential to achieving the specified schedule and cost goals (Lu *et al.*, 2018). Regretfully, a considerable amount of waste produced in the construction industry is caused by poor management of the material supply chain (e.g. delivery services, inventory, communications) (Irizarry *et al.*, 2013). Then, in an environment such as the construction sector with tough competition, adversarial relationships, and traditionally low profit margins, efficient material logistics is required as it is a key determinant of project success (Jáskowski *et al.*, 2018). In this regard, the use of information technology (IT) is suggested to achieve better logistics processes, avoiding delays and improving the integration process of the construction supply chain management (Irizarry *et al.*, 2013).

## **3. Materials and Methods**

The results presented in this document were developed in a 4 months investigation carried out within the framework of a professional master's degree. The research methodology was structured around 5 major stages: (1) review of literature, (2) gathering of information on site,

(3) logistic management prototype system design, (4) validation of the prototype and (5) analysis of results.

The first stage included the review of bibliographic material regarding the areas related to the subject of study, such as logistics and management of the supply chain, among others. The second stage was the gathering of information on site in three companies dedicated to the construction of buildings in Santiago, the capital of Chile. For these purposes, semi-structured interviews were carried out with workers from construction companies (professionals and technical personnel) that work on high-rise building projects. Based on the results of stages 1 and 2, the prototype of the logistics management system was designed and built, and later validated in stage 4. Finally, in stage 5, an analysis of the results of the prototype implementation was performed to obtain the main conclusions of the study.

#### 4. Results

In stage 2, we visited 3 construction companies, where a total of sixteen workers were interviewed. The detail of the interviewees is presented in Table 1.

Table 1: Interviewees information (source: Own elaboration)

Company/Position	Years of Work Experience						Total Interviewees
	Project Manager	Construction Manager	Site Manager	Technical Office Professional	Warehouse Chief	Planner	
Company 1	15	4	8	5	15	5	6
Company 2	-	3	20	4	4	3	5
Company 3	-	10	10	15	7	6	5

The interview included, in the first place, demographic questions such as level of studies, position in the company and years of work experience. Then a section was incorporated with questions aimed at characterizing the logistic management process of these companies, ending with a third section aimed at identifying possible improvements to the current system. The main results obtained in this interview process are presented below.

In the three visited companies, the relationship between those involved in the construction projects are very similar in terms of organizational charts, declaring internal and external agents that participate in the logistics management process. Among the internal agents involved are the project management team, the technical office, the warehouse chief and the head office of the construction company (when the company have a centralized system for procurement), while external agents include suppliers, distributors and subcontractors.

Regarding the structure of operation, company N°1 has an internal structure oriented to centralized purchases, but where the quantities and quality of the materials are directly controlled by the technical office professionals working at the project and the project management team. Company N°2 has a structure like that of company N°1, but who controls the quantities and specifications of purchases is the chief of the technical office of the project. The warehouse chief makes the materials requests that are informed directly to the chief of the technical office. In both cases purchases are made by the procurement department at the head office. In company N°3, purchases are made centrally by the department of purchasing and

logistics at the head office. This department defines the quantities and specifications of the materials. In this case the concern of the project team is only to request materials.

In the three companies, interviewees considered that there are deficiencies in the communication between the suppliers and the construction projects, especially in relation to the coordination of the arrival of materials to the site. This lack of appropriate planning generates problems at the project, causing the warehouse department to not meet the expectations regarding the coordination and planning of materials purchases. One possible reason for this is that the construction companies shows little concern about this topic, as they are worried about controlling purchases, but not necessarily about the arrival of materials. Because of this, it is necessary to have people in charge of planning the arrival of materials on site.

In relation to the operation of the warehouse, it is considered that in many cases it has not been professionalized nor has processes that help to minimize errors and plan on issues related to minimum stock of materials, requests for dispatches of materials from suppliers and coordination of timely arrival of materials, among others. In general, warehouse chiefs do not have professional or technical education, as they usually have been trained informally through work experience. For example, of the three warehouse chiefs interviewed, only one had technical education. Also, to manage the warehouse, they use their own notes, without any systematic methodology, relying on paper calendars and making annotations of the purchase orders on their notepads. Once the materials have arrived at the site, the sequence of unloading and use of the storage sectors is often granted to the most urgent orders, not respecting the previous planning of the orders and its coordination. This shows that there are no clear methodologies to deal with the large number of arrivals of materials on site, due to a lack of programming of those who request them, mainly construction project professionals, as well as the warehouse. In the case of the supply of materials, it is considered that there must be a strategy to standardize the processes, avoiding diverting the priorities of the participants in terms of tasks to be done. For this it is considered that there should be a greater participation and communication between the project manager, the technical office and the site professionals to avoid hasty requests for materials or requests that do not have consistent and complete information.

Another critical point to consider is how construction companies control the arrival of materials to the project. It is important to consider different factors to define a good strategy for this process, such as speed of unloading, permanence time of vehicles on site to unload material, planned storage of materials, among others. Also, the distribution of materials within the projects under construction is highly relevant. Many times, there is no control regarding the delivery of materials from the warehouse to the jobsite. As a result, this activity is not performed strictly according to the previously scheduled. One reason for this is that many times these building projects are executed on sites where almost all the available space is occupied by the building under construction. On these cases sometimes is difficult to have large warehouses for storage, and materials are leaving in the open, on the field. Then, construction materials are directly available to workers, who access them without strict control by the warehouse.

The external participants on this process that have greater involvement in high rise construction projects according to the interviewees are the suppliers, the distributors and the

subcontractors. The importance of establishing long-term relationships with suppliers is highlighted in order to eventually have more committed strategic partners. In addition, it is mentioned the importance of coordinating the transport of materials with the companies that distribute them in order to avoid problems of availability of schedules and fleets, among others. For this, an advance dispatch program must be managed, in order to obtain safeguards and commitments between the parties. Regarding subcontractors, coordination problems may arise when materials for them arrive unexpectedly at the jobsite due to failure to timely inform to the construction company of its arrival, producing different type of problems. For this reason, permanent communication is necessary during planning meetings to avoid problems that may have an impact on the progress of the project.

### **5. Contractor-Collaborators Logistics System Prototype Proposal**

This proposal aims to contribute to the improvement of current logistics management practices through a computational tool to monitor and control the programmed activities regarding this process, allowing a better communication among the contractor and its collaborators concerning logistic planning. The central elements of this proposal include the use of an email account and MS Excel, which requires a low initial investment, since both mentioned tools are of low cost, unlike the commercial software that exists in the market in reference to logistic management. For this prototype it was decided to use a Gmail e-mail account, which allows access to web tools such as Google Calendar, which is a web scheduling site that manages appointments and/or events with their respective schedules and timely reminders. This system is free, easy to access and manipulate. This web platform is linked to the tasks regarding logistics management perform by project participants, aiming to have the information about these activities on real time, optimizing the processes. Then, internal and external stakeholders of the project will have updated information about the logistic activities, providing greater reliability regarding the planned logistic actions on every stage of the project.

The main components of the system are presented below:

- **Project Activities Calendar:** Having a tool that can inform about the time available for the arrival of material to all the participants is useful for the logistic management from both internal and external collaborators and improves the internal communication of the project. In this proposal construction companies are responsible for updating the schedule for the arrival of project materials. The person in charge must send a three-week calendar for the activities, that is, the current week, plus the consideration of the next two weeks. The communication is through emails notifications as official means, given the speed of updating and the possibility of making changes periodically. Having this calendar allows that each participant of the logistic process can consult about the time available to schedule the arrival of materials in a specific date.

- **Request for Materials and Services Form:** The request for materials must be validated by the professional responsible of its approval before being processed. Because of that, these professionals must spend more time planning to properly use the methodology for requesting materials, but as a result they could anticipate possible risks and their impact on the execution of the project according to their constructive sequences. Figure 1 highlights the form to request



materials for a construction project. This form includes the following information: project name; requested by; order number; materials; quantity; unit, observations; name of the Construction Manager and its sign; approval date; authorization of the cost department and its sign; request date; and reception date. Each process must have a revision date.


		<b>REQUEST FOR MATERIALS AND SERVICES FORM</b>			Code: R-PO-01-03 Revisión:00 Date of issue: 09-27-2017	N° 1
Project name: XXXX		Requested by: YYYY		Order number:		
PEP SAP	MAT N°	Materials	Quantity	Unit	Observations	
Name of the Construction Manager		Signature	Approval date	Reception date		
Authorization of the cost department		Signature	Request date	Reception date		

Figure 1. Request for Materials and Services Form

- **Materials Arrival Programming Form:** This document provides the necessary information to feed the web platform (Google Calendar) with materials arrivals requests, avoiding the scheduling of different activities at the same time with negative impacts on the critical path of the project. Thus, once the system manager receives the requests for materials, it is possible to coordinate the dispatch according to the needs of the project. Professionals in charge of logistics must satisfy critical stocks, granting dispatch planning with different priorities in dates and times. In Figure 2, an entry form for the arrival of material is presented. The required information to schedule the arrival of materials to the project include 11 elements: 1) name of the project, 2) requested by, 3) supplier or subcontractor name, 4) description of the required material, 5) unit, 6) purchase order, 7) material state, 8) schedule date and time of arrival, 9) schedule date and time of departure from site, 10) real date and time of arrival, and 11) real date and time of departure from site. This form is used by the internal participants of the construction project, where the professional in charge of logistics act as the planner in conjunction with the field professionals, to give an adequate priority to dispatches. In parallel, there is participation of companies providing services to the construction company.

- **Materials reception form:** This form allows the evaluation of the performance of the activities regarding logistics through an MS Excel spreadsheet that records the data delivered by the other forms and the schedule developed using the Google Calendar platform. These data will be processed later by performance indicators.

- **Record of reception of materials:** It corresponds to the registration of activities through an MS Excel spreadsheet that contains the data of the previous forms. These data are processed allowing the analysis of the logistic management processes regarding the level of fulfillment of the different participants. An example of the information on these spreadsheets is shown on

Figure 3. This table include information such as ID of the arrival, name of the supplier, contact person, telephone number, date schedule for arrival, including day, month, year and time, and date schedule for departure, including day, month, year and time. Other reports created with this information include a Time for Unloading Report and a Permanence Overtime Report.



**MATERIALS ARRIVAL PROGRAMMING FORM**

1 Name of the project ..... Date of request: .....

2 Requested by: .....

3 Supplier or SC name .....

4 Description of the required material: .....

5 Unit of material: .....

6 Purchase order: .....

7 Material state: .....

8 Schedule date and time of arrival: .....

9 Schedule date and time of departure from site: .....


10 Real date and time of arrival: .....

11 Real date and time of departure from site: .....

**Note: Material**  
 SW: Structural Work  
 FS: Finishing stages

\_\_\_\_\_ Name and signature

Figure 2. Materials arrival programming form



ID	Company information			Date schedule for arrival				Date schedule for departure			
	Supplier	Contact person	Telephone number	Day	Month	Year	Time	Day	Month	Year	Time
1											
2											
3											
4											
5											
6											
7											
8											
9											

Figure 3: Example of record of reception of materials form

To use the prototype, the first thing to do is create a Gmail email account where the username must be the respective project name. Once the email account has been created, it is possible to deliver the password to the process participants, keeping in mind that there should

always be a moderator or administrator of the account that must work in the construction company, ideally a professional from the technical office, to avoid programming problems among the different requests for arrival of materials. This professional must evaluate the priorities of the different materials request, according to the needs of the project and periodically inform the committed dates of arrival of materials to the jobsite.

Also, it is important to conduct an induction session with the members of the project team regarding how the prototype operates, especially to those employees whose decisions have a direct impact on the logistic processes of the project, such as site professionals, technical offices professional, warehouse employees, logistics specialist and construction head office professionals, among others. In addition, the external participants must be included, such as suppliers and subcontractors. This should be done in the weekly meetings, in project dependencies, to become familiar with the new methodology.

The construction company will oversee the implementation of the logistic system. Therefore, it must have the tools previously indicated to develop the prototype and timely notify the availability of schedules to both internal and external stakeholders so that they can proceed with their programming.

## **6. Prototype implementation**

Next, the application of the prototype in a construction company is described, where a professional recount the experience before and after working with this system. Subsequently, an application example is described that highlights the benefits in cost due to having a correct logistic management methodology.

### *6.1 Situation before using the prototype*

To understand how logistics management was carried out before the prototype was used, an interview was conducted with the Site Manager of one of the construction projects visited, who agreed to test the prototype. The interviewee points out that in previous projects he did not control the materials purchased or its arrival to the site, nor the entry of labor subcontracts and/or general subcontracts. They operated through telephone calls and emails to place a request for purchase of materials and/or equipment rental that must be authorized by the project manager. The interviewee points out that this way of work has been used for a long time in Chile, although in recent years, different information technologies tools have been developed allowing the improvement of the processes. Throughout his work experience, the professional interviewed has worked with MS Project to program the structural work and finishing stages of the construction project, focusing on meeting deadlines and not on the logistics aspects of the project. Also, the interviewee points out that it is increasingly difficult to control the arrival of materials in the project, so that fines are often received for excess of trucks parked on the public road due to the arrival of materials. This leads to unloading of materials by order of arrival or by urgency, creating problems with supply companies, transport drivers, the community, and inspection entities, among others.

In general, there was no communication between the people in charge of logistic with providers of materials to plan the supply, generating problems because the materials were not

requested in time by the construction company, or because there was no response from suppliers according to schedule.

## 6.2 *Experience after using the prototype*

The professional interviewed points out that the use of the prototype improved the logistic processes, although at the beginning the implementation of the system was difficult, but through the fulfillment of weekly meetings, plus the incorporation of a professional from the construction area to the warehouse management, the logistic area start to receive more relevance within the project, highlighting the need for good communication between the parties.

When the prototype was incorporated, the original material request forms were modified, including date and delivery times for validation of the project manager. This allowed for the regulation of the quantities of materials requested, as there was a debate between the areas of administration, site and logistics prior to the purchase of the materials. In addition, by having a system of forms for requesting materials, it was clearly identified who made the order and the sector of work associated, for example, site professional in charge of underground and exterior; site professional in charge of the structural work or site professional in charge of finishings, generating a greater concern for requesting materials on time.

Subsequently, changes were made in the internal coordination meetings. At the weekly team meeting, a special period was dedicated to the area of logistic management. Initially they explain the current problem with the arrival of materials and how they were going to implement a tool to schedule the arrival of materials for contractor suppliers, concrete suppliers, debris removal, among others. Then began the incorporation of the prototype on the daily tasks, working also with subcontractors. Planning meetings were held to present this new way of working around logistic management in the project and present those employees of the construction company with responsibility on the process inside the project. The supplier companies recognized the importance of the new process and appreciated the way to present the information to them, since previous communication was often through telephone and emails without getting to know the people with whom they been working for a long period of time.

With respect to the subcontractor companies, it was a bit more difficult to implement the prototype due to their problems to purchase materials from their own suppliers. To solve this problem, it was requested that the control of the arrival of materials become part of the activities performed by the subcontractor. That is, not complying with the requested control could cause questioning during the approval of the documents to give course to the payment.

Contractor professionals emphasize that by having a clear work methodology, positive changes are generated in relation to the planning of all the participants, both internal and external. This generates greater concern for the work itself and the relationships among the work perform on the jobsite and logistics management.

Once the methodology for requesting materials and to schedule its arrival was in place, better communication was generated among all the participants allowing to use the spaces according to schedule and generating restrictions to receive materials in project dependencies known by all. This forced supplier companies to adapt to the scheduled configuration and not

send materials without programming. For the logistics area the resolution of this issue was important, since then it allows them to better organize and attend their work with greater freedom.

Since part of the structural work of the building and the finishing activities are carried out at the same time and the high number of trucks at the project site becomes complex, this project considered the reception of finishing materials only on Mondays, Wednesdays and Fridays of each week. This measure was adopted to give greater emphasis to the reception of concrete on Tuesdays and Thursdays, with the purpose of not obstructing the days programmed for the reception of materials of the finishing stage and to avoid congesting the site. The supplier companies aligned with this decision and the results were favorable over time, as suppliers now know that the contractor will not receive materials without programming and even less in the days where the arrival of finishing materials was prohibited.

Finally, the interviewee highlights the incorporation of tools that can improve the performance of the planning and programming process, as week after week the compliance of internal and external collaborators regarding the logistic schedule was presented at planning meetings. In this case, it was considered that the prototype was useful and that it allows to perform a more professional job assuming a low financial cost, requiring personal and group dedication to develop teamwork both within the internal and external participants.

The following is an example of improvement when using this prototype. The benefits are mentioned around planning resources and costs. The construction companies when scheduling orders for materials to be used in the project's finishing stage contacts their suppliers to schedule specific dates and times of materials dispatches. At the same time the contractor company can choose to rent equipment to carry out the unloading of materials (e.g. fork crane and/or tower crane). The option of using mechanical equipment in the unloading of materials generates a benefit in the non-use of direct labor, as its use give more speed to the process, and at the same time making it possible to program the arrival of a greater quantity of materials for the same day, in order to optimize the use and rental of equipment. About the suppliers, they receive benefits in the reduction of time of permanence on site. In the case of having a schedule agreed by both parties (Construction Company - Provider), they can receive significant benefits for their internal programming routes reducing the cost of transport for excess of permanence on site, since many times the supplier companies sub-contract the transportation services.

It must be mentioned that both parties have benefits, mainly in planning and programming resources. The need to seriously comply with the request forms for programming the arrival of materials is fundamental, given that afterwards a control of the programmed is carried out using information from the real performance of the process. When analyzing the causes of non-compliance, the responsibility of the reasons and/or causes of nonconformance can be dealt with seriously.

Finally, thanks to the recording of reception of materials through the information entered in the forms, variables such as programming, unloading time, overtime permanence on site, among others could be analyzed. This allows evaluating the compliance level of the logistics planning, detecting possible problems, triggering the investigation of the causes of non-

compliance and at the same time generating the possibility of taking timely decisions to avoid future complications regarding the logistics management of projects. For example, Figure 4 shows the measures regarding the speed of unloading. This task can be performed according to the scheduled time or may take longer than expected. With the above it is possible to evaluate overtime of permanence on site during the arrivals of material, as shown in Figure 5. This analysis allows the construction company to evaluate the performance of their suppliers, identifying their main deficiencies. Through a good communication among both parties these problems could be reduced or eliminated, improving the results of the logistic processes and reducing undesirables cost such as fines for excess of trucks parked on the public road.

Suma de Tiempo de descarga	Proveedores				
Tiempo (Min)	Escombros	Petreatos	Silcosil	Tabiques	Total general
7-9-2016	25	103	49		177
8-9-2016	30			77	107
<b>Total general</b>	<b>55</b>	<b>103</b>	<b>49</b>	<b>77</b>	<b>284</b>

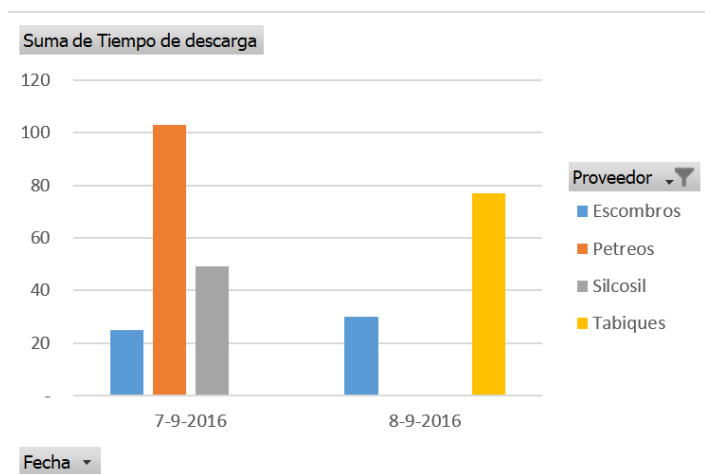


Figure 4. Time for unloading from different suppliers (in minutes)

Suma de Sobretiempo de estadia (MINUTOS)	Proveedores				
Fecha	Escombros	Petreatos	Silcosil	Tabiques	Total general
7-9-2016	13	27	8		48
8-9-2016	15			46	61
<b>Total general</b>	<b>28</b>	<b>27</b>	<b>8</b>	<b>46</b>	<b>109</b>

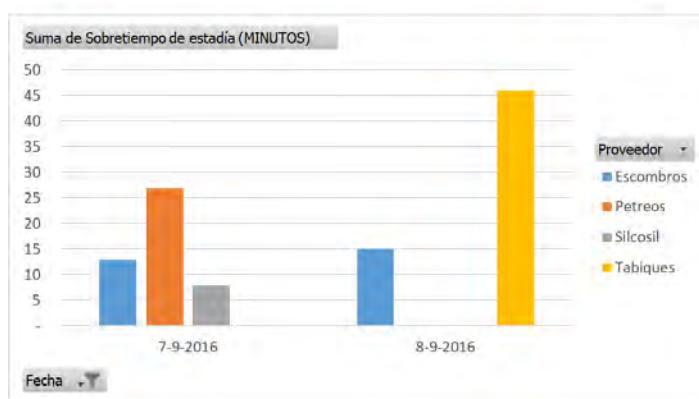


Figure 5. Overtime regarding material unloading from suppliers (in minutes)

## 7. Conclusions

This article presented a Contractor-Collaborators Logistics System Prototype for construction projects, with a focus on the area of high-rise building. This proposal incorporates concepts of planning and programming into the logistic management area, where the prototype's attention is concentrated in the supply of materials. Through the information obtained in the bibliographic review and the visits made to three construction projects it was possible to develop a work methodology supported by the prototype. The application of this methodology generates information for the participants involved in the logistic process that previously was not available. In fact, it was common to not have information of logistical requirements due to a lack of planning and programming. Having a web platform such as Google Calendar that is able to notify the activities to be carried out regarding logistic management through emails and also having a calendar available for all the participants to scheduling their future jobs, generates benefits for a construction company, according to the experience described by the construction site professional that lead the prototype implementation of this system in a construction project.

In addition, the study shows that the participation of external agents is necessary to develop alliances of commitments (Construction Companies - Providers of Services and/or Supplies) and establish benefits for both parties, since good communication is a central part of the proposal.

Finally, with this prototype it is possible to control the planning and programming of logistic activities and monitor their compliance conditions, through the data gathered in the different forms included in the system, comparing the results with the original planning of the process. In addition, the results are easy to present and evaluate in meetings with the participants, to subsequently improve the processes. In summary, it is a tool that provides benefits to different areas of a construction project, especially logistic management, with a low investment, unlike other available logistic management systems that requires higher investments and maintenance costs, and often do not deliver the expected benefits, given that those systems do not know the real situation or work practices of the logistic sector of high rise building in Chile.

This study highlights the importance of the logistic management within construction projects and the need to develop more studies in the area to improve the processes performance through logistics management software or tools that helps to enhance the planning and programming of the logistic activities. Future research could include the development of a mobile version of this platform using technologies such as cloud computing to allow the access to the information regarding the logistic process from anywhere and at any time using mobile devices such as smartphones. Cloud computing is considered very useful for small and medium size construction companies, as it reduces the need for an in-house IT department and their associated cost, allowing at the same time the storage of great amounts of data. This is a good opportunity to improve and professionalize the logistic processes within construction projects. In addition, it is necessary to emphasize that in this area the participation of qualified personnel to assume responsibility is vital to maintain the appropriate control of the logistics management processes.

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# The Influence of Trust and Culture upon Western Consultants Executing GCC Megaprojects

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## **Abstract:**

Western consultants must build trust filled relationships if they wish to successfully engage with the local project sponsor to manage GCC megaprojects. Initial research indicates a high staff turnover for senior western consultants in GCC megaprojects. This paper reviews trust issues contributing to these high levels of turnover and the influence of national culture in this process. Softer skills such as cultural awareness and trust are often ignored until the issues become out of control and too late to address. European megaproject research confirms that culture has a powerful influence on the construction of megaprojects, and cultural clashes negatively impact their execution. The concepts of culture and national culture are reviewed, together with cultural guidelines established by Hofstede and others. Established research has explored typical characteristics exhibited by national culture, offering guidance for differing attitudes with respect to trust between different nationalities.

This research analyses the experiences of the western consultant's actively involved in live GCC megaprojects, using Qatar as a pilot study. Initial findings are provided, which acknowledges trust as a crucial element to both the megaprojects success and the consultants continued project engagement. It also considers the cultural expertise available to help unite parties within these temporary megaproject coalitions and assist with the successful delivery of future megaprojects. Prominent trust issues in the GCC, such as the concept of face, are reviewed. The practical and social implications for western consultants' cultural integration to the GCC are examined.

*Keywords: trust; national culture; G.C.C Megaprojects*

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## **1. Introduction**

The discovery of vast reserves of oil in Saudi Arabia in the 1930s had a profound influence on the physical, human, and political geography of the Middle East, and the world economy. The wealth created by oil in the GCC nations (the Cooperation Council for the Arab States of the Gulf, known as the Gulf Cooperation Council), has led to considerable inward investment on large scale infrastructure and other capital construction projects. Many of these projects fall within the definition of 'mega-projects', characterised by a long project duration, a complex contractual nexus, technical complexity requiring specialist skills, and the need to create a temporary project organisational coalition for the design, management, execution and delivery of the project. Such projects require large numbers of professional consultants as part of this

temporary project coalition. A skills shortage in the professional services necessary for the volume of projects in the GCC has led to professional consultants mostly being appointed from outside the GCC - predominantly from Western Europe and North America. Individual consultants are generally employed on such megaprojects by large multi-national construction consultancy firms on fixed-term contracts.

National restrictions on land ownership and access to finance mean that in the GCC, the project sponsors are in every case nationals of the country in which the project is carried out. This sponsorship has given rise to two related issues. Firstly, that which arises at the national cultural interface, and secondly that which occurs at the professional/lay client interface. These are considered separately for this paper, although in practice they are inexorably linked.

Professional groups control a body of knowledge which is applied to specific tasks (Elliot, 1972 p 11). The project sponsors control the land, the capital, the regulatory framework, and the terms under which the professional consultancy service is provided. This professional/laity 'power relationship' (Foucault, 1982) requires a high degree of mutual trust to give this business efficacy. In addition to this professional relationship, for mega projects, in the GCC there is the added complexity of the social/cultural interface with western consultants, arising from differing belief systems, social and cultural norms, and rules and traditions governing status, interpersonal conduct and business relationships.

At the heart of this is the need for trust at a personal, professional and commercial level. Trust influences the ability to form stable (working) relationships (IPMA, 2015, p. 72,89) and it is argued that the presence of a high level of mutual trust is a crucial factor in successful megaproject delivery. This paper reports on the findings of an initial investigation into trust issues between GCC Employers and western consultants employed to manage the construction of GCC megaprojects. Early findings suggest that when trust breaks down, senior western consultants are often removed from the megaproject – their contract is terminated. These losses can result in significant disruption and cost to the project from among other things loss of essential project knowledge, the need to procure and contract with new personnel, and the need for induction and initiation in the project process and procedures.

The individual experiences of western consultants actively involved in GCC megaprojects are the subject of this research, which examines the relationships between national and organisational culture and trust. The study aims to add to the current body of knowledge by providing an objective and measured contextual analysis of the impact of cultural differences and levels of trust on the successful delivery of the contractual obligations typically undertaken for GCC megaprojects.

The paper begins by defining contextual trust and culture and setting this within the context of the GCC. This introduces the concepts of trust and culture and positions the paper about the existing literature and studies into national cultural influences in the GCC. The paper reviews current research on European megaprojects and the findings from these which may be replicated in GCC megaprojects. The process of 'cultural integration' is evaluated together with an examination of the validity and usefulness of the application of conceptual cultural measurements developed by Geert Hofstede (Hofstede, Geert, Hofstede, Gert Jan, Pedersen,

2002). Finally, the paper sets out the methodology proposed and applied in for an ongoing empirical investigation into GCC megaprojects. It is anticipated that this will allow the discovery of any norms that can be applied to derive focal characteristics of culture and trust and enhance the existing body of knowledge. The findings to date are analysed and presented in the form of a narrative with illustrative quotations to strengthen the trustworthiness of the methodology. The discussion considers possible implications in practice and suggests future research directions and the limitations of the work to date.

## **2. Contextual background to Trust issues.**

Trust is described as an ‘invisible structure of social reality’ (Seale, 1995), and is considered an essential component of the relationship between project parties such as employers and contractors, project managers and stakeholders, consultants and contractors. The concept of trust has been widely studied from a social science, organisational, and social psychology perspective. Trust is a multi-dimensional concept. For this research, trust is the following definition provides a useful starting point. Trust is the *willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party* (Mayer, Davis, & Schoorman, 2014, p. 712). More specifically the research focuses on ‘gaps in trust’ that exist or arise between GCC project sponsors (typically referred to as the ‘Employer’ in construction contracts), and western consultants engaged in managing megaprojects in the GCC.

The influence of trust and culture has been explored by several researchers for European megaprojects (Smits and van Marrewijk, 2014; van Marrewijk, 2007; Van Marrewijk, Veenswijk, and Clegg, 2014; van Marrewijk, Ybema, Smits, Clegg, and Pitsis, 2016). In Arabic culture, the trust often centres around existing personal or family relationships. These hierarchies of trust have been described as being initially to self; then to a kinsman, townsman, tribesman; and finally to those with a shared religious background (Meyer, 2014, p. 171; Moran, Harris, & Moran, 2011, p. 260). Lewis, (2016, p. 146) demonstrates the nature of this relationship hierarchy through a ‘trust circle’, with family at the centre and foreigners forming the outer perimeter.

Trust varies according to the level of expertise expected from each of the parties. An example of differing requirements in the level of knowledge demanded from local and western consultants was highlighted in a recent field interview with a western cost consultant. He described a contract in which a GCC project sponsor engaged a family member who had recently acquired a construction company, to perform a minor aspect of a project (the site accommodation set-up works). The family member’s firm was unable to meet the contractual standards and instead of then applying the defined contractual remedies - the application of penalties - a decision was made to nurture and support the family members firm until the project was eventually complete, disregarding the contractual obligations which would typically have been applied with a western consultant.

GCC project sponsors contract with large numbers of firms from outside the GCC to carry out the construction works for megaprojects. The degree to which GCC project sponsor engages

western consultants to provide professional expertise, knowledge and skills in building is indicated in Table 1. Table 1 also combines World bank data, (2016) for GDP and estimates of the native population of the GCC as twenty-six million (data.worldbank.org). In this paper, Central Intelligence Agency data is used to arrive at the percentages of expatriates active in the GCC, and the estimated value of construction turnover is derived from a study by international Cost Consultants AECOM, (2018).

	GCC State	Total Population	Expatriate Population	Expatriates Residents	% Expats in Construction	GDP USD Billion	Value of Construction USD, Billion
1	Qatar	2,639,211	2,111,369	80 %	50%	167.605	46.4
2	KSA	32,938,213	10,500,000	32 %	36%	683.827	109
3	UAE	9,400,145	7,800,000	83 %	30%	382.575	87.7
4	Kuwait	4,136,528	2,895,570	70 %	17%	120.126	12.6
5	Oman	4,636,262	2,086,318	45 %	31%	72.643	15.2
6	Bahrain	1,492,584	666,000	45 %	22%	35.307	7.7
7	Totals	55,242,943	26,059,256	47 %	31%	1,462,083	279

**Table 1** – GCC Statistics (AECOM, 2018; Central Intelligence Agency, 2019; World bank data, 2019) **Expatriate Statistics** Qatar [www.mdps.gov.qa](http://www.mdps.gov.qa); Oman [www.ncsi.gov.om](http://www.ncsi.gov.om); Bahrain [www.blmi.lmra.bh](http://www.blmi.lmra.bh); UAE [www.grc.net](http://www.grc.net); Saudi Arabia ; Kuwait [www.ceicdata.com/en/kuwait](http://www.ceicdata.com/en/kuwait)

This data demonstrates that a significant volume of expatriates employed in the GCC construction sector, and this ranges from thirty-two per cent in Saudi Arabia to eighty per cent in Qatar. Construction related personnel account for between seventeen and fifty per cent of all expatriates. Construction-related activities currently account for nineteen per cent of the GCC's Gross Domestic Product. Over nine million expatriate construction staff are employed on GCC mega-projects, making these projects *multicultural* (Dulaimi & Hariz, 2011) *often comprising an extensive gathering of culturally diverse hired in expert consultants* (Archibald et al 1991) while they *draw from a pool of highly qualified resources around the world* (El-sabek, 2017). Based on the pronounced cultural differences typical on GCC Megaprojects (by contracts to European megaprojects which are typically more mono-cultural), this paper argues that current megaproject management research has not focused on the potential significance and effects of GCC megaproject cultural differences to date. The aim of this is to provide a complete understanding of culture and trust influences in GCC megaprojects, and the possible implications of this for successful project delivery.

## 2.1 Professional Trust

Western consultants engaged in GCC megaprojects are appointed to provide their particular professional knowledge and expertise, to supplement or in place of local consultants. Foxwell, (2019, p. 14) describes the expert in the consultant industry as someone with *a knowledge base, institutionalized training, accreditation, peer control and a code of ethics*, and that the services provided *need to be independent, .... free of bias and have the all-important commitment to the greater good* (Foxwell, 2019, p. 214). Wates (2016) argues that professionalism is as essential in the construction industry as the standards of care provided by experts in medicine. Expectations of high levels of competence and expertise are not limited to

the GCC. Two wide-reaching government-sponsored studies into the UK construction industry, "The Egan Report", (1998) and Latham's "Constructing the Team Report", (1994) highlighted the confrontational approach typically found in construction projects. A recent study by Foxwell notes more generally that there is *a general breakdown in trust in almost all institutions, and particularly in the opinion of 'experts'*. (Foxwell, 2019, p. xx10). In positive settings, the trust generally grows as the parties become more familiar with each other, and as the professional working relationship develops. Meyer (2014, p. 190) describes how a good personal connection is the *single most important factor* when doing business in the Arab world. Familiarity is also described as a precondition for trust (Lewis, David J., Weigert, 1979).

### 3. Conceptual Background to Culture

Culture has been described as a *fuzzy, complex and inconsistent phenomena*" (Alvesson, 2002, p. 14; Schein, 2004, p. 12). There are many varied interpretations of culture (see for example GLOBE, 2004; Schein, 2004; Trompenaars & Wolliams, 2003) and this can range from 'culture' meaning an appreciation of classical music, to culture as a series of systemised and deep-rooted beliefs and core values held by individuals and nations (Kendall, Gavin, Wickham, 2001).

For clarity, this research is concerned with the consideration of culture as a set of shared national or professional beliefs and considers an appropriate description of culture as *a set of norms and skills that are conducive to survival in a given environment*, (Inglehart, 2018, p. 16). Hofstede (1991) defines culture as *"the collective programming of the mind which distinguishes the members of one group or category of people from another"*. Culture itself is considered as both invisible and intangible, and there is considerable complexity in measuring what anthropologists label as "beliefs" "values" or "dynamic phenomena" (G. Hofstede, 1991; Koopman et al., 1999; Schwartz, 2012). The ability to capture and define culture leads to this being a contested term, and critics such as Mcsweeney, (2002, p. 90) suggest that one is *"attempting to measure the unmeasurable"*. None the less, anthropologists and others have provided useful tools that may be helpful at some level in measuring and conceptualising (see G. Hofstede et al., 2010; Smith, Peterson, & Schwartz, 2002; Spony, 2014).

#### 3.1 Measuring Culture

Waisfisz (2015) suggests that culture only exists by comparison, and therefore, one method to compare countries is where a benchmark score can be provided to allow comparisons to be drawn. Although potentially reductionist, to measure 'culture' it is often deconstructed into the essential elements that comprise an overall "culture", through the identification of unique features (or sub-sets). The sum of these sub-sets provides a global outlook considered as a "national culture". Different scholars have applied different and often unique labels for their sub-sets, variously describing these as "dimensions" (Hofstede and Pedersen, 2002) or "values" or "orientations" (Strodtbeck, 1961). Scoring mechanisms are often used (see, for example, Hofstede, 1991; Inglehart, 2014; Schwartz, 2012; Spony et al., 2014; Trompenaars and Williams, 2003). As a working proposition for this research, national culture is considered as *"the name we give to that which distinguishes the people of one country from those of another"*

(Hofstede and Pedersen, 2002 pxviii). It is suggested that issues of trust – the presence or absence of this to degrees - forms an integral component of national culture.

National culture has been identified and explored by researchers including Strodbeck, (1961); Hofstede, (1991); Schwartz, (1999); Trompenaars and Woolliams, (2003); GLOBE, (2004); Ronald Inglehart, (2014), for half a century. Kluckhohn and Strodbeck (1961) identify the sub-components of national culture as “value orientations” and identify five possible descriptions and criteria for these value orientations: (1) human nature orientation; (2) man-nature orientation; (3) time orientation; (4) activity orientation; and (5) relational orientation (Kinasevych, 2010 table 1.1). Schwartz identifies ten dimensions as ‘common values’ which he suggests are universal (Schwartz, 2012). GLOBE acknowledges nine ‘cultural dimensions’ (Shi & Wang, 2011) identify six “dimensions”, similar to those described by Hofstede. To make such intangible characteristics measurable Spony, Trompenaars, Hofstede and others, allocate a numeric value to each cultural dimension. In such a contested area it is unsurprising that social scientists apply different interpretations to the same countries, and that there is no universal or consistent acceptance of any single model.

For the GCC states, Hofstede measured the Kingdom of Saudi Arabia, the Sultanate of Kuwait and the United Arab Emirates (Hofstede, 1991). Trompenaars and GLOBE have both studied the GCC states of Kuwait and Qatar (Baumann, 2013; Shi & Wang, 2011, p. 95). The World Values Survey (WVS), will complete their current cycle of global surveys in 2019, and this will include Saudi Arabia and the U.A.E. The WVS updates their models regularly and map cultural shifts through an interactive map ([www.worldvaluessurvey.org](http://www.worldvaluessurvey.org)).

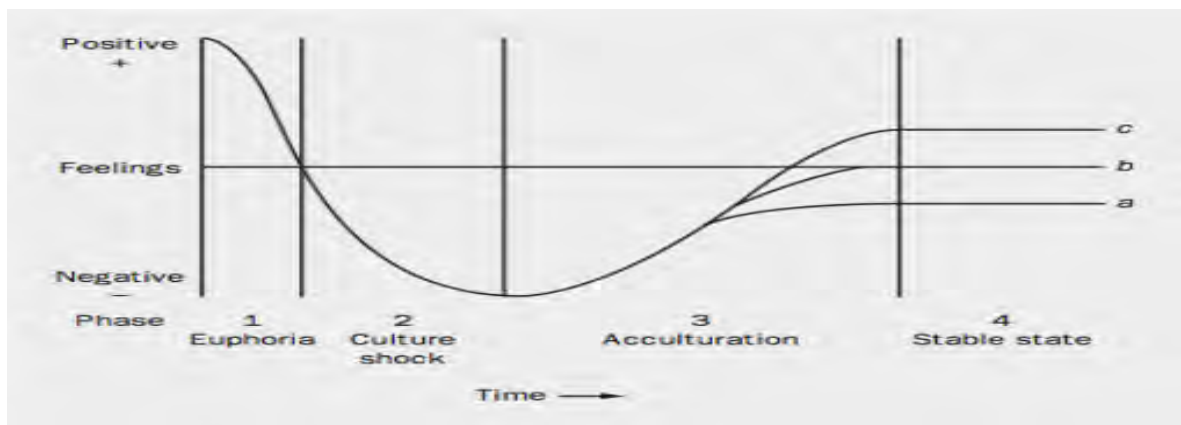
The set of cultural measurements developed by Hofstede cover eighty-five per cent of the GCC population, and this provides the most comprehensive current set of measures available for the GCC. To date, several studies (Beugelsdijk, Maseland, & van Hoorn, 2015a; G. Hofstede & McCrae, 2004; R. F. Inglehart, 2018) have tested individual dimensional scores from Hofstede’s original findings, and their results suggest that the data concerning his dimensions remains valid. For example, Beugelsdijk, Maseland and van Hoorn, (2015) replicated Hofstede's dimensions for 'individualism' and 'indulgence', and their findings suggest “*the Hofstede dimensions relative to the scores of other countries have not changed very much....and are generally stable*”.

### 3.2 Cultural Integration and ‘culture shock.’

Lewis (2016, p. 19) describes the individual’s experiences of ‘culture shock’ as an *uneasy feeling* in which “*precious values and unshakeable core beliefs take a battering when we venture abroad*”. Hofstede describes the process as *the visitor in a foreign culture returns to the mental state of an infant, in which the simplest things must be learned over again. This experience usually leads to feelings of distress, of helplessness, and hostility toward the new environment* (G. Hofstede et al., 2010, p. 384). Canadian anthropologist (Oberg, 1960) is generally credited with first describing the concept and coining the term “cultural shock”, which he describes as the state of anxiety and frustration resulting from the immersion in a culture distinctly different from one's own.

Researchers, in many cases, identify “stages” of cultural shock, with the perceived number of stages fluctuating according to the level of detail recognised. Some suggest a six-stage cyclical approach comprising 1. Preliminary → 2. Spectator → 3. Participation 4. → Shock stage 5. → Adjustment and 6. → Re-entry (Moran, Harris and Moran, 2011 p212-216). The Project Management Institute (PMI) recognises nine steps (Kay, 2014- p249). It is common to encounter is a four-stage approach (sometimes with an extra step). The extra step is reintegration to one’s original culture, or “re-entry stage” (Moran, Harris, & Moran, 2011, p 274).

A typical 4 stage approach is shown in Figure 1.

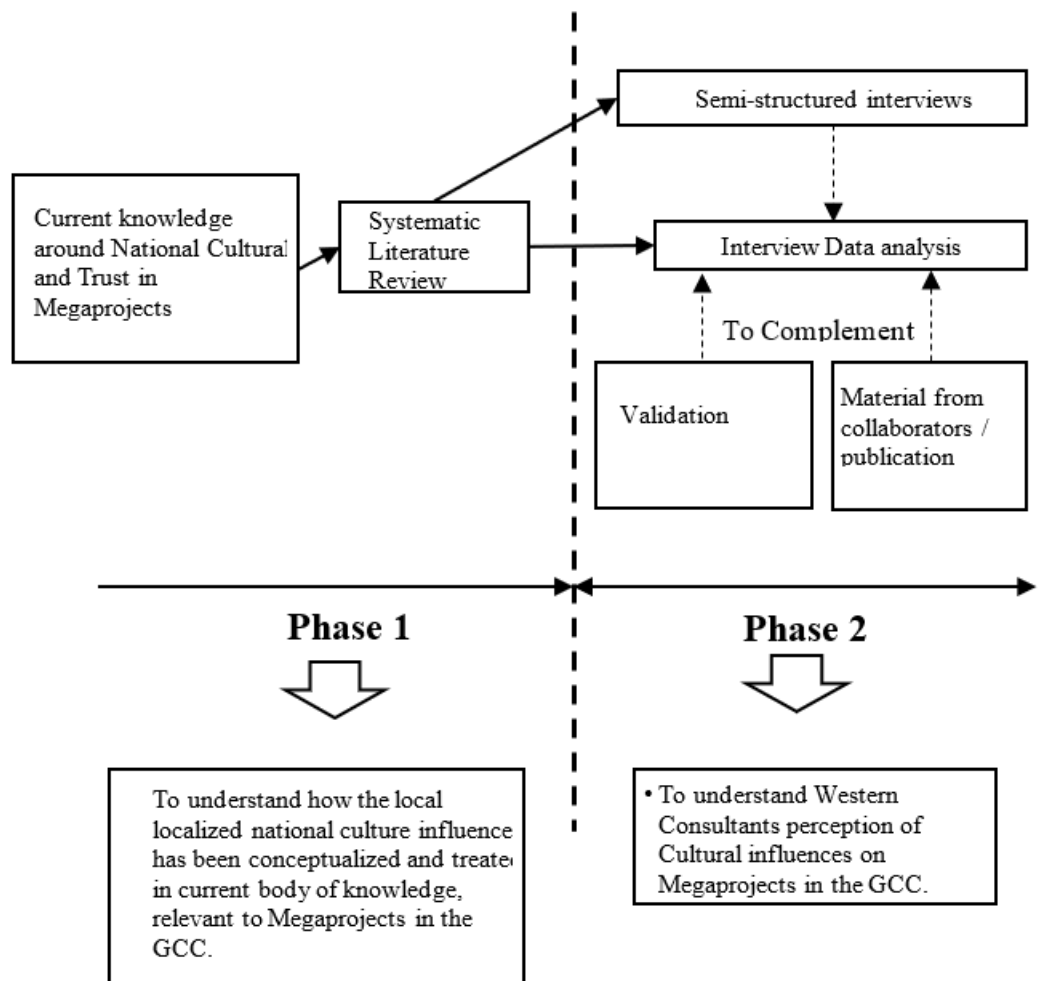


**Figure 1** - abstracted from Hofstede’s “ Exploring Cultures” (Hofstede, 1991a p385)

In Hofstede’s portrayal of cultural shock, the first journey is a feeling of euphoria, a honeymoon, filled with the excitement of travelling to a new land; then culture shock occurs when real life starts, and the new environment kicks in. Acculturation follows as the outsider slowly learns to function in the new environment, accepting some of the local values, and integrates (with varying success) into a new social network. Hofstede describes the final integration as a stable state of mind (from Hofstede, 1991a p384-385). It is interesting to note that those interviewed to date as part of this research, perceived that the settling in period - Stages Three and Four (acculturalization and stability) was typically between twelve and eighteen months.

#### 4. Materials and Methods

The research described in this paper adopts a two-phase approach: firstly through literature review and secondly through empirical field research. This approach is shown diagrammatically in Figure 2 below.



**Figure 2**– Conceptual representation of the research method adopted from Teo and Loosemore (2014)

#### 4.1 Phase 1 – Literature Review

The extent to which national culture exerts influence on construction projects in the GCC has been explored by many including Harrison and Michailova, (2012) Baumann, (2013) At-Twajjri and Al-Muhaiza, (1996) Newman and Nollen, (2016) Jaeger and Adair, 2013 and Mais Sartari (2010). Haak-Saheem (2016) outlines specific disparities between GCC and western culture. Harrison & Michailova (2012) studied the roles of expatriate females living in the GCC. Baumann (2013) specifically focused on time overruns related to National Culture influences. At-Twajjri and Al-Muhaiza, (1996) studied the GCC’s oil industry, and Sartari (2010) conducted specific research examining one particular group of western consultants. Haak-Saheem (2016) specifically researched the potential introduction of public-private partnerships in the GCC. Al-hashemi (2016) reviewed the influences of organisational culture on Kuwait’s construction industry. There are also several cross-cultural studies suggesting differing cultural approaches to management within the GCC, such as Bakhtari, (1995); Chapman, (2004); and Jaeger and Adair, (2013).



Outside the GCC there is extensive research on megaprojects (Smits and van Marrewijk, 2014; van Marrewijk, 2007; Van Marrewijk et al., 2014; van Marrewijk et al., 2016) including the Panama Canal extension, the OMEGA megaproject in France (a French high speed rail system), Netlipse (a network associated management of large infrastructure projects in Europe), Nabucco (a 1300 km pipeline through Turkey, Austria, Bulgaria, Romania and Hungary where researchers have found that culture and trust are critical to the successful completion of European megaprojects (Rafindadi, Mikić, Kovačić, & Cekić, 2014; Suprpto, Bakker, Mooi, & Hertogh, 2016; Van Marrewijk et al., 2014). This research has identified cultural issues amongst the management team leadership/governance as a “*significant risk*” that requires “*special considerations*” and management during the lifecycle of the megaproject (Biesenthal et al., 2018; Smits & Brownlow, 2017; van den Ende & van Marrewijk, 2015). Merron, (1988) researched the failure of global megaprojects and concluded that *megaprojects are large bundles of risk compounded at every corner, including political, financial, time and culture and strongly recommends that that one considers culture within all future megaprojects* (Merron, 1988 p vi). However, little attention has been directed to the impact of culture upon GCC megaprojects, to date. From this literature review, it is evident that there is a current gap in knowledge explicitly relating to GCC research on the influences of culture in megaproject management.

#### 4.2 Phase 2 – Research Methodology

This research utilizes the principles of grounded theory as a *fruitful way of exploring a substantive area about which little is known* Barrett & Sutrisna, (2009, p. 936) and qualitative studies involving purposeful sampling is engaged until the juncture where data received reached saturation point (Barrett & Sutrisna, 2009; Glaser & Strauss, 1967; Prior, 2008; Saunders et al., 2008). As the research draws on the experience of practising participants, semi-structured interviews are engaged, in preference to structured or in-depth interviews. The semi-structured interviews investigate the viewpoints of western consultants by recording their personal experiences. The research focuses on particular features of GCC culture. It commences with their social integration (seven specific questions); then their professional integration (nine issues). It then examines their experiences with culture shock (five issues), and details any cultural preparations that were made or that they suggested might have been useful (eight questions) before engagement in the GCC.

The results of the interviews were thematically analysed, and the results collated. The credibility of such research is, of course, endangered by the potential of bias. In an effort to mitigate the impacts of researcher bias, findings are triangulated with specialist talent management (HR) departments. Additionally, participants were requested to review, verify and endorse a transcript of their interviews.

#### 4.3 Hofstede’s existing GCC Cultural Measurements

The pioneering works of Geert Hofstede (Hofstede, 2011; Hofstede et al., 2002) remains crucial to the understanding of national culture. Hofstede has developed “cultural dimensions” that measure the cultural tendencies of 82 different countries, 2010, fig. 2.2 excluding duplicated countries). These dimensions include power distance; individualism; masculinity;

uncertainty avoidance; long term orientation; and indulgence. Several studies have reviewed the individual dimensional scores from Hofstede’s original findings (Beugelsdijket al., 2015a; Hofstede and McCrae, 2004; Inglehart, 2018), and suggest that the original data remains broadly applicable. For example, Beugelsdijk, Maseland and van Hoorn, (2015) replicated Hofstede's dimensions for Individualism and Indulgence and their findings suggest “*the Hofstede dimensions relative to the scores of other countries have not changed very much....and are generally stable*”.

Hofstede asserts that there are six dimensions to a National Culture. The Hofstede Institute describes the dimensions, as shown in table 2.

Power Distance (high versus low) The extent to which the less powerful members of a society accept that power is distributed unequally	Uncertainty Avoidance (high versus low) The extent to which people feel threatened by uncertainty and ambiguity and try to avoid such situations.
Individualism (Individualist versus Collectivist) Collectivism: people belong to in-groups (families, organisations, etc.) who look after them in exchange for loyalty. Individualism: people only look after themselves and their immediate family.	Long Term Orientation (long term versus short term orientation) The extent to which people show a pragmatic or future-oriented perspective rather than a normative or short-term point of view.
Masculinity (high versus low) Masculinity: the dominant values in society are achievement and success. Femininity: the dominant values in society are caring for others and quality of life.	Indulgence (Indulgence versus Restraint) The extent to which people try to control their desires and impulses. Relatively weak control is called “Indulgence”, and relatively strong control is called “Restraint”.

**Table 2** Source : (Culture ComPass™ Consolidated Report, 2014)

Hofstede has measured the first four dimensions for what he describes as “The Arab World”, including Saudi Arabia, Kuwait and the United Arab Emirates (Hofstede, 1991). A comparison of differences in cultural dimensions between the “Arab World” and western cultures often involved nationalities identified through field research (as Table 3) in supporting the GCC megaproject. Cultural dimensions associated with several participating nationalities are set out in Table 3 below.

Index Scores for Countries and Regions				
	Power Distance Index	Uncertainty Avoidance Index	Individualism / Collectivism Index	Masculinity / Femininity Index
Country				
Australia	36	51	90	61
Belgium	65	94	75	54
France	68	86	71	43
Great Britain	35	35	89	66
Ireland	28	35	70	68
New Zealand	22	49	79	58
South Africa	49	49	65	63
United States	40	46	91	62
Regions of Arab Countries	80	68	38	53

Table 3 Hofstede’s Cultural Dimensions in Numbers- Figures Abstracted from (G. Hofstede et al., 2010, pp. 6–20)

Table 3 provides numeric values for the score for each country. Through comparison of the delta (found by subtracting the scores between the states), cultural differences can be anticipated. In simple terms, the higher the delta in the scoring, the more significant the culture gap between the nations. To explain these gaps by example, an indicative difference for dimensions associated with power distance (which represents the ‘distance’ between the country’s leader and the public); for the Arab nations, a score of 80 reflects the absolute monarchies typical of Arab states. Whereas western nations such as Ireland (28) or the USA (40) have a much lower power distance between the ruler and the public, as would be expected for an elected and democratic government.

Cultural scoring mechanisms indicate the cultural differences between Arab and Western cultures in other dimensions.

Differences in dimensions indicate the following trends:

**Power Distance:** Arab Countries have high power distance tendencies where societies have more respect for the position, age, status and rank. Conflict and negative talk are kept private, as raised voices or public humiliation is considered extremely disrespectful.

**Individualism:** The GCC is a collectivistic society with a close long-term commitment to the member ‘group’, be that a family, extended family, or extended relationships. Loyalty and culture are paramount and override most other societal rules and regulations.

**Masculinity:** There are family and moral values associated with caring for extended family and caring for others, which may take precedence over the need to be successful.

**Uncertainty Avoidance:** The GCC exhibits a high preference to avoid unpredictability.

## 5. GCC field research

Details of GCC megaproject awards are published in the online construction journal ConstructionWeekOnline.com, (2017). This journal collects and publishes tendering information, contract awards, and commercial updates for the GCC construction market. It provides information related to projects drawn from government reports and through information obtained from consultants working in the region. In this research, Megaprojects in the GCC were considered as these in progress between 1999 to 2018. This data was carefully screened, as several megaprojects were deferred between the years 2015 and 2018, due to the low price of oil (Deloitte,2016). Each megaproject was analysed to check if it had been suspended, completed or remained active. Cross verification was applied through consulting with specific megaproject websites, professional consultants' websites, newspaper project announcements and local consultant knowledge. This process identified a total of 185 live megaprojects, in November 2018 in the GCC states.

After identifying these active megaprojects, the western consultant firms employed on these megaprojects were identified. This research confirmed that twenty-two firms of western consultants were engaged with megaprojects in Qatar. In 2016, the GCC introduced a blockade where access to Saudi Arabia, the UAE, and Bahrain were banned (BBC, 2017). As over half of all GCC western consultants operated in Qatar in tandem with other GCC states, it was feasible to consider a case study within the state of Qatar (November 2018), while additionally seeking clarifications from western consultants for any regional differences in approach throughout the GCC.

### *Applying a GCC lens through Qatar*

Live megaprojects were considered to ensure that the information would be of benefit to current practitioners. There were seven live megaprojects identified to form the research sample, as detailed in Table 4.

	Name of the project	Category	Classification of project	Value (USD Billion)	Status Nov 2018
3	Musheireb Development	Building	mixed use	5.00	Ongoing
14	Doha Metro	Infrastructure	Metro	46.80	Ongoing
16	Lusail Development	Building	mixed use	48.65	Ongoing
17	New Doha International Airport	Infrastructure	Airports	11.00	Phase 2 Ongoing
19	The Pearl Qatar	Building	mixed use	5.00	Ongoing
21	New Doha Port	Port	Port	7.40	Ongoing
22	The 7 Stadium for the FIFA World Cup 2022	Building	mixed use	10.00	Ongoing
23	Qatar Water Reservoirs	Water Transmission	Water transmission	4.60	Ongoing
Totals				158.45	8 Live

**Table 4** Live megaprojects in Qatar at December 2018

### *Purposeful selection*

Purposeful sampling methods (Hoepfl, 1997; Leedy & Ormrod, 2015) were adopted for this phenomenological inquiry, which seeks to understand cultural influences in GCC megaprojects. Sixteen methods of purposeful sampling ranging from extreme or deviant case sampling to convenience sampling are identified by Patton and others (1990, pp. 169-183). This research focuses on *typical case sampling*. To ensure an adequate breadth of sampling the investigation, once completed, will include participation by at least one western consultant from all live megaprojects in the state of Qatar (Table 4). Differing timelines may distort the results, so the research was limited to megaprojects which were active in November 2018. In-depth first-hand knowledge was provided by director-level participants. This research has shown that GCC construction directors (or equivalent) have a significant span of experience, generally having between five and twenty years of experience in the GCC and occupy the most senior position within their organisation in the GCC. The terms of the project contract generally provide that they are the person empowered to endorse or receive formal communications and to manage their internal staffing requirements (FIDIC, 1999).

The directors of the consultancy firms interviewed come from differing professional backgrounds, including architects, cost consultants, project management or claims consultants. After obtaining ethical consent, directors were approached, and the purpose and requirements of the interview were detailed. To date, twenty have participated, and three have declined citing either workload or confidentiality concerns.

Following agreement to participate semi-structured interviews were held typically lasting for between one and two hours per participant. These interviews allowed the researcher to observe the participants' reactions to questions, which provided a more in-depth understanding by giving knowledge of the context in which events occurred (Hoepfl, 1997). For higher reliability, meeting minutes were produced, jointly reviewed and confirmed. The participant was also requested to take part in a further fifteen-minute cultural aptitude survey, which was undertaken online with the Hofstede Institute. These results were required to authenticate the usefulness of existing Hofstede institutes' researches.

### *Initial Results:*

There is a wealth of information published to date concerning cross-cultural research (for example see Hammerich & Lewis, 2013; Hofstede, 2010; M. Javidan, 2009; Moran et al., 2011; Trompenaars, 1993). There is also research specifically focused on international management of projects (see, for example, Archibald, 1991; Minor, 1999; Obikunle, 2002). One objective of this research is to extend and make more useful the knowledge and information available to western consultants relating to cultural issues that typically arise on megaprojects in the GCC. Additionally, this research aims to contribute to both the body of research associated with megaproject development; and to cross-cultural research in the global multicultural environment. Findings are presented in the form of a narrative with illustrative quotations to enhance the trustworthiness of the adopted methodology. Five aggregate themes are provided as headings 5.1 to 5.5. The response considers existing advice from cross-cultural researchers to compare the initial findings of empirical research with existing data. for western consultants

in active GCC megaprojects. The analysis and inherent reasoning behind each of the propositions is provided and connected to these themes is as follows:

### 5.1 *Proposition 1 Social Integration: Western consultants should be better prepared for social integration in the GCC*

Some cross-cultural commentators advise that ‘when in Rome, you should do as the Romans’ (Hammerich & Lewis, 2013; Meyer, 2014). Others suggest reviewing the countries *cultural mindset* before engagement, through following a framework such as understanding the type of culture, understanding the differences with your own, respecting the differences and enriching yourself through the new (Elena, 2010). National characteristics associated with Arab nations include suggestions that they are family orientated, conservative, religious, and consultative - not individualistic (Bakhtari, 1995; Erin, 2014; Moran et al., 2011). Cultural commentators also warn of the dangers of leaving your home country to escape *back home* issues, such as relationship or career issues (Moran et al., 2011)

For this research, participants were requested to provide their regional ethnic background, from a selection of the Americas / Europe / Asia / Africa & the Middle East / Australia. The respondents are almost equally split between Europe and Africa and the Middle East. In some instances, participants addressed this research based on citizenship they had been granted, as opposed to their place of birth.

Participants from Africa and the Middle East described the least social integration issues as most had prior links to the community. For others, mainly Europeans, social integration was restricted with many stating that they felt significant restrictions compared to those experienced in Europe. The responses of one Quantity Surveyor that the social side “*it is not for everyone*”, related to facilities being closed at prayer times, particularly at weekends, the need to wear more modest clothing, and the fact that Saudi Arabia was considered very restrictive for females. Most perceived the procedures for getting visas, official permits and any documentation as highly bureaucratic.

The most common perceived benefits were related to health and a tax-free lifestyle, although many reported that these benefits, had reduced in recent years. Most participants recommended the lifestyle. However, a commonly expressed included a perception of increased spending power “*if the money isn’t tax-free, I wouldn’t be here*”). All participants recorded that primarily, their social engagement was limited to interactions with other expatriates and not GCC residents.

### 5.2 *Proposition 2 Professional Integration: Western consultants should be advised of the professional differences to be encountered and the need to build trust between the parties.*

There are some aspects to each profession that cannot carry through all regions, so a *healthy dose of particularism* is often required (Trompenaars & Wooliams, 2001). From the onset, it is likely that the consultant will become part of a *cultural soup*, and may benefit from a framework to manage multicultural teams (Zein, 2015; Ochieng & Price, 2009). Cross-cultural commentators advise that *nothing happens quickly* and *trust is paramount* (Moran et al., 2011), and that trust is built up in Arab nations *based on relationships* (Meyer, 2014, p. 171) There are

more significant risks associated with cultural miscommunication at professional levels. For example, a severe cultural mistake would be to embarrass one's host in public, leading to a loss of "face". Despite suggestions that *society has become more tolerant over the years*, the concept of *face is still prominent within the Middle East and in the Far East* (Webb, 2015, p. 262). One of the easiest ways to cause someone to lose face is to "*insult an individual or criticise them in front of others*" (Hammerich & Lewis, 2013, p. 222). Hofstede records that sometimes a "*loss of face can be felt more painfully than physical mistreatment*".

For differences between professionalism in the home nation in the GCC, the profession of the consultant seemed to influence his perception. For example, significant architectural practices indicated that design parameters were similar throughout the world. Likewise, cost consultants advised that their cost reporting and estimating were identical. While the presentation and content remained generally consistent, the parties reported notable differences were related to the highly developed output demanded and to time frames set, which were frequently unrealistic. They elaborated on the time required to build trust between themselves and the project sponsor, which they found more difficult than building similar relationships in their home country. A standard view expressed was that the unrealistic time expectations resulted in extended working hours leading to a poor work/life balance. An early finding of the study is that the respondents found professional integration a lengthy process, often requiring up to eighteen months to feel professionally accepted.

### 5.3 Proposition 3 Culture Shock: *Western consultants should prepare better to reduce the impacts of cultural shock*

An emerging finding of the research was that there were extensive education and project qualifications, which were a pre-requisite to western consultants' consideration for engagement on a GCC megaproject. The New Doha International Airport, the Metro and the new Port all required a minimum of fifteen years post graduate experience, in addition to specific project related experience, and a minimum of five years working in the GCC. Despite this requirement for prior local knowledge, most respondents were aware of megaprojects from which key personnel had been removed due to cultural differences. Many participants expressed concern about the threat of project removal. Despite assurances of confidentiality, two firm's directors refused to provide an interview due to concerns based on a perceived job endangerment associated with speaking about such events.

Once key project personnel were removed, respondents cited a slowdown in project productivity, an increased perception of job instability, and reduced morale, all because of such removals. One respondent referred to a very high frequency of replacements in three of his recent GCC megaprojects leading him to suggest. *You're no good unless you have been kicked off at least two projects and it happens every day*. More than half of the respondents believe it was *highly dangerous* to have of public disagreement with their Arab counterpart, with many considering this as a critical reason for removal from a project. As part of the on-going research, a project-specific case study is being undertaken to provide additional information to explain this phenomenon better.

#### 5.4 Proposition 4 Preparation for the GCC: Western Consultants should be offered training before emersion in the GCC

Cross-cultural experts suggest that cross-cultural preparation can offer benefits including less turnover of staff, resulting in reduced 'return costs' and better performances, productivity and profitability (Moran et al., 2011). This research found that over one-third of participants had received some form of educational training or preparations in advance of their assignment in the GCC. This training ranged between a three-day workshop (one instance) to one-to-one counselling for a duration of between two to five hours for three participants. The participants felt that this had been useful, and the respondents who had received training suggested that they had 'fully acclimatised' in twelve months, slightly under the average fourteen-month acclimatisation period described by others. Those that had not received any form of training suggested that such training would be beneficial. In follow-up questioning, over 60% believed that this would be best provided by external consultants. Only one participant expressed the view that you could *not prepare in advance*.

#### 5.5 Proposition 5 Application of Hofstede's Cultural Compass: Western Consultants can be better prepared for the entry to the GCC by reviewing existing national culture traits.

More than half (60%) of respondents completed the Hofstede Cultural Compass survey. This survey provides feedback to the participant on several aspects of cultural integration. Firstly, it advises them of the culture dimensions expected from their own national culture. Secondly, it gives them an individual ranking against their national culture score. The ranking may indicate that their culture is not in line with the collective position of their home nation. Thirdly - and most critically - it compares the cultural tendencies inherently acquired through home cultural behaviour with cultural differences they are likely to experience in the GCC. During the interviews, participants respond to specific questions related to their attitudes towards project issues. Topics include working relationships, control levels, punctuality, change management, and customer orientation. Such questions are designed to derive their preferences for their work environment, the levels of authority they feel should be applied to their work, and a series of rules to follow. Respondents were generally satisfied that the data produced was indicative of their experiences with the GCC to date, except for two participants, one who queried the value of the data, and another who felt the differences between his host country scores and his personal culture scores were inaccurate. Feedback from participants of the survey ranged from "*interesting questions*" to most commonly a "*very useful tool*".

### 6. The disruption caused by a breakdown in trust

It is suggested (Harrison, 1994, p.18; Leiß, 2013 p.29) that the employer incurs costs for every premature departure of up to \$1,000,000 per employee. The respondents surveyed to date were not prepared to disclose the actual costs associated with the removal of personnel from projects. However, it is evident that the financial losses related to such calculations do not include the intangible costs associated with the early departure of key personnel. Interviews recorded intangible difficulties faced by the project, including project disruption, lower staff morale, loss of momentum and loss of reputation. Further research and data collection beyond



this paper, is required to explain and appreciate the fuller scale of the losses incurred when key people depart the megaproject.

### 6.1 Cultural Assistance

Cross-cultural researchers such as (G. J. Hofstede et al., 2002; R. Inglehart & Wayne, 2000; Moran et al., 2011; Schwartz et al., 1999; Triandis, 1993) have identified the substantial differences between Western and Arab cultures for decades. They offer their services *to decode other cultures* to avoid *misunderstanding, needless conflict and ultimate failure* (Myer, 2018, p. 12). There are both organisational level resources such as the Hofstede Institute ([www.hofstede-insights.com](http://www.hofstede-insights.com)) or Trompenaars THT institute (<http://www2.thtconsulting.com>), and individual experts such as Omar Zein (Zein, 2016) and Karen Smith ([www.crossculturework.com](http://www.crossculturework.com)). They aim to assist with analysis, provide bespoke educational training courses or detailed reports outlining the measures necessary to succeed in the Arabic culture. They can provide individual or group specialist advice for the preparation required to acclimatise. Their recommendations often include cultural alignment, cultural collaboration, acknowledgement of soft skills associated with personnel (Struggles & Heidrick, 2015), and open cross-cultural communications (Kardes et al. 2013). They promote flexibility by first understanding your own culture and having a willingness to integrate with other cultures (Elena, 2010; Zein, 2015). This concept is acknowledged by Schein, (2004, p. 7) who recommends that we “*need to see the world through cultural lenses*”. Despite the availability of such professional advisors, those surveyed to date had little to no intercultural training. During semi-structured interviews, participants acknowledge the need for cultural training and most respondents foresee a significant benefit to such training. Further research is needed to review and to test the efficacy of what is available and marketed as cultural consultancy advice.

## 7. Conclusions

The value of GCC megaproject is estimated at \$279 billion or 19% of GCC GDP, as referenced in Table 1, and an estimated 146 western consultants are active in this market. There has, however, been limited research to date that examines the experiences of western consultants active in or entering this market. This research examines the intersection of two areas in the megaproject construction sector: trust and cultural issues. This research captures the experiences of western construction consultants operating in the GCC construction sector.

Preliminary findings to date suggest a widespread lack of trust between the parties. These trust issues can provide a negative effect on the success of GCC megaprojects. As a megaproject team becomes more cohesive with greater cultural unification of the group, then lessons from megaprojects such as the Panama Canal (van Marrewijk et al., 2016) shows that this will result in improved delivery.

Given the high value of megaprojects currently underway in the GCC and recognising the high replacement costs of a single principal consultant, this research is essential, both in contributing to improving project cost efficiency and in enhancing project performance.

The early findings of the research suggest that there is a high number of Western professional consultancy staff regularly removed and replaced. The study identifies that staff

replacements are in some cases, the result of miscommunication, loss of trust between the parties, or a failure to appreciate the cultural differences between the parties. This research revealed a limited number of western consultants in the GCC who were able to successfully navigate these issues as evidenced by their longevity of project tenure. The initial findings support the idea that cultural integration requires the acquisition of soft management ‘people-skills’ and *understanding how people tick* (Hillson, 2009). These observations are echoed by specialised recruitment agencies such as Struggles & Heindrick, (2015) who suggest that a critical requirement for placing executives in megaprojects is the need for “*directors to learn the soft skills necessary to manage cultural differences*”.

### 7.1 Further researches

This paper reports on an active research project. Although the initial findings are of considerable interest, and interesting patterns and trends particular to the experience of Western Consultants on mega projects in the GCC begin to emerge, there is more work to do to test the validity and applicability of the findings. More data and a complete interrogation of the data is planned over the next two years.

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# Determinants of Cost Overrun and Schedule Delay in Tunnel Megaprojects

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## Abstract:

This paper aims to determine the most influential factors of typical cost overruns and schedule delays in tunnel construction megaprojects. Based on an empirical dataset of tunnel megaprojects built internationally, the authors conduct analyses of variances and linear regression modeling to infer statistical significance and understand the relationships that are likely to exist between cost overruns, schedule delays and project, technical, and governance factors of a sample of tunnel megaprojects. The results suggest that the most significant factors are those related to the project complexity such as the length of the tunnel, the total length of the tunnel tubes, the number of cross passage tubes, and the type of project delivery system. Despite expectations, the type of infrastructure, region, ownership, and funding scheme are not likely significant factors of cost and schedule performance. Tunnel construction practitioners can benefit from this research findings in their attempt to help improve the performance of future tunneling megaprojects and making better technical and managerial decisions. Lastly, this novel analysis affirms that the size and complexity of tunnel megaprojects are important determinants of the low performance that is typically measured in such kind of megaprojects.

**Keywords:** *construction management; cost; schedule; megaprojects; project management; tunnel construction*

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## 1. Introduction

Megaprojects are most often unsuccessful as they typically fail to meet expected levels of cost and time performance (Muller and Judgev, 2012). Substantial cost overruns and schedule delays are usual problems in megaprojects leading to disappointing outcomes (Lehtonen and Martinsuo, 2006). Megaprojects are characterized by design complexity, number of stakeholders involved, huge budgets, and long durations so that a small change in the project input may reflect in a large and escalating effect in the output.

As part of the wider category of megaprojects, large-sized transport tunnel construction projects show very low cost and time performance, specifically. This is probably due to the inherent characteristics of tunnels. In fact, multiple design disciplines, diverging interests of a variety of stakeholders ranging from promoters to local communities and governmental agencies, resource and capital intensity, tough environmental requirements, technological challenges, and major uncertainty make it hard to appropriately estimate and manage project time, cost, and risk so that tunnel megaprojects often result in significant cost escalations and time delays out of the original schedules and budget targets (Narbaev and De Marco, 2017; Flyvbjerg et al., 2007).



Recent studies show that, despite their growing popularity, construction megaprojects often fail to meet original cost estimations, time schedules and other project outcomes (Van Marrewijk et al., 2008). As a consequence, the high rate of failure experienced by infrastructure megaprojects has originated several studies to examine the factors that can contribute to their success (Joslin and Muller, 2016). Previous works have placed emphasis on project cost escalation factors (Shane et al., 2009), complexity and risk factors (Creedy et al., 2010; Kardes et al., 2013; De Marco et al., 2017). With this regard, a founding empirical study to understand the factors of typical poor performance in transport infrastructure megaprojects is the one by Flyvbjerg et al. (2003b, 2004). In their work, they analyze 258 large-sized transport projects developed in 20 nations worldwide and conclude that cost overrun and time delay in megaprojects are a widespread global reality, without statistically significant difference on historical period, region, or mode of transport. The conclusions drawn are an average cost escalation of 45% for rail projects, 34% for fixed link projects, such as tunnels and bridges, and 20% for road projects. Also, they report that cost overrun depends on three main factors: the length of the implementation phase, the size of the project, and the type of property (Flyvbjerg et al., 2004). More recently, researchers have started to widen the scope of possible failure factors and focus more on the structural characteristics of the project context and its impact on success. According to a study by Asvadurov et al. (2017), infrastructure megaprojects with budgeted cost greater than one billion US dollars are delayed by one year and exceed the expected budget of over 30% on average.

Another important factor that has been given the attention of researchers is the governance of megaprojects. This stream of literature identifies the structural characteristics needed for successful project execution. Project governance is about the use of delivery systems, structures of authority, and processes to responsibilities and control a project with the objective to support projects in achieving their cost and time objectives. In this context, some authors have been seeking to explain the significant performance problems exhibited by many transport megaprojects and critically examined their suggested governance solutions (Sanderson, 2011).

However, few previous studies are available to explore the factors of low cost and schedule performance of transport tunnel megaprojects: the literature largely reviews cost and schedule in transport infrastructure megaprojects, but little mention is given for tunnel projects overall, and their cost and schedule performance in particular. For instance, Reilly and Brown (2004) have anticipated that mechanisms to incorporate management and control of risk are an important factor to mitigate cost escalation in tunneling projects.

In this paper, we carry out a novel empirical analysis on 39 tunnel megaprojects built worldwide in order to identify the main determinants of cost overrun and time delay. This is an attempt to help improving performance of future tunneling projects and establishing better organizational and managerial policies when dealing with such infrastructure megaprojects.

The remainder of this paper is structured as follows. The next section introduces the dataset collected from the 39 tunnel projects and the research methodology. Then, the paper presents the exploratory descriptive statistics and the linear regression modeling results subdivided into project, technical and governance groups of variables that may influence cost and schedule performance. After that, the main findings are discussed with practical implications and

limitation of the study. Finally, the conclusions are derived with the summary and future research directions.

## **2. Materials and Methods**

### *2.1. Data Collection*

This study collected data from tunnel construction megaprojects developed or in progress over the last 20 years. The minimum budget is greater than \$500 million (approximately €400 millions). The authors used the following three sources to collect the data: 1) the second-hand search in available web-based project databases, scholarly publications, official websites by governmental agencies, project promoters and general contractor; 2) available studies from the World Tunnel Congress 2017 Norway Bergen (9-15 June 2017); and 3) the first-hand data via an online questionnaire administered to the project promoters or sponsors of the identified 39 tunnel megaprojects.

### *2.2. Methodology*

The research approach included two stages. On the first stage, the authors conducted an exploratory analysis with the purpose to capture the main characteristics of the dataset of tunnel megaprojects. On the second stage, the study analyzed using an inferential statistics. The aim was to detect possible relationships, if any, between the identified variables of interest.

The dataset of the project factors was grouped into three categories of variables. The first category were the project variables such as location, the period when the tunnel is excavated, durations of the approval period and implementation phase, investment size, final cost overrun and time delay. The second category of variables includes the technical variables such as the type of tunnel, physical characteristics of the tunnel, and the excavation method. Lastly, the third group on the governance variables included factors such as the delivery system, project ownership, source of funding, and type of relationship between owner and contractor. With this regard, the authors were interested to determine whether these project, technical and governance factors may have a statistical relationship with project cost and schedule performance.

For the purpose of this study, time performance was measured as the percent fraction of actual duration minus the scheduled duration over the scheduled duration. As for cost performance percent variation, this was measured as the actual final cost minus the original budgeted cost over the budgeted cost. With this regard, the study applied both one-way ANOVA and simple linear regression methods to determine whether their differences were statistically significant.

The null hypothesis of the model was that the means of the samples to be compared were the same: for this hypothesis to be rejected, the p-value must be less than 0.1. If it was below 0.01, the difference was strongly significant; between 0.01 and 0.05, significant; between 0.05 and 0.1 weakly significant.

The following assumptions of the regression model were tested using the SPSS® software. In particular, in order to verify the first assumption of homoscedasticity, which is referred as to the homogeneity of the variances within the layers, the Levene test was used. The Levene test's

null hypothesis was that the variances were equal within the layers: if this showed significance lower than 0.05, the interpretation was that the variances were not homogeneous and therefore it was necessary to proceed with other tests than ANOVA to verify the equality of the compared sample means. To test the second ANOVA assumption, which was the normality of a dependent variable within different groups, the Kolmogorov-Smirnov test was used. Its null hypothesis stated that the distribution of a variable was normal.

In cases where these two assumptions of the ANOVA model were violated, the authors had to apply a non-parametric test: the Mann-Whitney's non-parametric test, extending to the Kruskal-Wallis test for the cases with more than two groups (Kruskal and Wallis, 1952).

### **3. Results and Analysis**

#### *3.1. Projects Exploratory Analysis*

Some main characteristics of the projects are reported in this section. Out of 39 tunnel projects, 7 were still into their design and planning stage, 19 were in progress and 13 were completed. 18 were announced earlier than the year 2000, 16 from year 2000 to 2010, and 5 after 2010. 13 projects were longer than 10 years, 20 projects lasted from 5 to 10 years, and just 6 were shorter than 5 years. Here the duration was defined as the period from the date the project was publicly announced by the promoting government to the start date of traffic operations. The size of capital expenditure ranged from €0.5 billion to more than €4 billion, with 19 projects less than €2 billion, 6 from €2 billion to €4 billion, and 14 larger than €4 billion. The dataset includes 56% projects developed in Europe, 28% in Asia, 3% in the North America, 8% in the South America, and 5% in Australia.

Appendix A presents the list of the projects analyzed in this paper. In particular, with regard to the type of a project, 19 tunnels were railroad infrastructures only, 9 were used for road vehicles, and 3 v mixed usage and 8 metro lines. One tunnel was dedicated to freight transport only, 10 projects were for people transport, while remaining 28 had a mixed-use purpose. 23 projects were alpine base tunnels, 10 projects were urban infrastructures and 6 were in other non-alpine landscape settings. 23% projects were transnational tunnels.

The collected projects' data can be subsumed into project, technical and governance categories of project variables. Table 1 presents some of the project factors of the sourced tunnels. The average cost overrun and schedule delay of the sample projects were 27% and 34%, respectively. This is consistent with Flyvbjerg et al. (2003b) who record an average cost overrun of 34% for both tunnel and bridge projects. In particular, the average time delay was approximately 1.6 years. The average approval period, referred to as the preliminary time period before the project is initiated, from the date the project is publicly announced to the date it is formally authorized was 7.8 years with a high standard deviation: it took more than 25 years to some projects to be initiated.

Table 1. Main project characteristics

Variable	Unit	Min	Max	Mean	St.Dev.
Cost overrun	%	-3	132	27	31
Schedule delay	%	0	100	34	29
Scheduled duration	Years	2.0	17.0	7.1	4.0
Approval period	Years	0.0	25.0	7.8	7.5
Excavation phase delay	Years	0.0	6.0	1.3	1.6
Budgeted cost	Billion €	0.50	9.61	3.37	3.01
Capex per km	Mln €/km	10.20	176.6	53.2	32.70

Table 2 reports some of the technical characteristics that may be impacting on the cost and schedule performance of the tunnel megaprojects. As part of these variables, the physical length of the project and the type of excavation are expected to influence the project performance.

Table 2. Technical characteristics of the sample projects

Variable	Unit	Min	Max	Mean	St.Dev.
Infrastructure length	Km	5.0	135.0	52.4	39.3
Tunnel length	Km	2.8	85.0	24.6	18.9
Total length of tunnel tubes	Km	4.5	230.0	57.2	53.4
Internal diameter of single tube	M	5.0	16.0	8.4	2.3
Distance between tubes	M	0.0	40.0	29.3	13.0
Maximum altitude	M	-390.0	4080.0	583.7	1041.2
Maximum slope	%	3.0	72.0	21.7	17.8
Number of cross passage tubes	Units	4	268	81	64
Distance b/w cross passages	M	100.0	3144.0	461.4	543.3
Tunnel Boring Machine (TBM) excavation portion	%	0	100	65	35
Number of TMB used	Units	1	21	4	4.5
TBM length	M	85.0	450.0	170.5	102.9
TBM weight	Ton	100	3400	1685	986
TBM diameter	M	5.8	13.7	9.2	2.0
TBM average speed	M/day	8	26	16.7	6.3
Traditional excavation speed	M/day	3.7	6.0	4.7	1.0
Excavated rock volume	Mln M <sup>3</sup>	0.1	19.0	6.6	6.3
Excavated rock weight	Mln Tons	4.0	40.0	17.7	13.4

Finally, several governance issues may be important factors of project performance. To analyze whether these aspects may influence the project schedule and cost performance, the dataset included information related to the project delivery system, financing mechanism, payment scheme, and project management service.

In particular, 51% of projects were directly delivered by the national ministry of infrastructure or public agency using traditional contracting mechanisms; for 20% of the projects a state or publicly-owned project company was created; the remaining 19% projects were developed by a privately-financed project company shared by construction companies, service operators and other equity investor. The two Chinese projects belonged to this last category although the shareholders were government-owned. In summary, 39% of projects were developed by a special purpose vehicle (SPV) that acted either as a Design-Builder (DB)

only (21%) or as a concessionaire responsible for all project lifecycle stages of design, build and Operations&Maintenance (O&M) (18%). The concessionaire SPV was either public (10%) or privately-owned (8%), which led to using a Build-Operate-Transfer (BOT) form of project delivery system (De Marco et al., 2012).

As per the financing mechanism, 74% of the tunnel projects resulted to be totally funded with public sources of funding, while remaining projects were developed under a project financing mechanism so that the SPV was responsible for providing, in part or in total, the sources of funding. These come under the forms of both equity and debt financing (Finnerty, 2007).

When it comes to the payment scheme, in approximately 70% of projects the contractor was paid a lump-sum fixed price, for 27% of projects construction contractors were reimbursed based on a unit price scheme (such as price per km of excavation, etc.), and only remaining 3% had a cost plus fixed fee payment contract (Villalba-Romero and Liyanage, 2016). A third-party construction project management company, as defined by De Marco (2018), was hired in 67% of the projects.

Finally, as far as the O&M service contract was concerned, 20 tunnels were directly operated by the government and associated governmental bodies, 6 were assigned a specific O&M service contract, and the remaining 13 projects were operated and maintained by the same SPV which was also responsible for the design and build phases.

### 3.2. The Regression Analysis: The Project Factors

The following three sections present various Anova, Mann-Whitney, Kruskal-Wallis tests and regression analyses to determine the existence of a statistical relationship between the main project, technical and governance variables, on the one side, and cost overrun and schedule delay, on the other side.

*Influence of Type of Facility.* First, the type of facility, namely rail, road, mixed use, or metro tunnel, did not prove any significant relation with project schedule and cost poor performance. However, direct comparison of rail tunnel projects versus all other types of infrastructures as a group showed a little significant difference in schedule delay and can explain a likely, tough weak, impact on the schedule delay of the sample projects (Table 3). In particular rail tunnels proved a shorter schedule delay than other facilities. However, this result may reflect the definition of schedule performance itself, referred here as the ratio of schedule variance over the original duration, so that a longer duration leads to a smaller percent schedule delay (Hoffman et al., 2007). In fact, the average duration of rail tunnel projects was 8.6 years, compared to 6.4 years for road tunnels, 5.6 for mixed use, and 4.7 for metro lines.

Table 3. Relation between rail tunnels and project performance

Performance variables	Rail Mean	Rail St.Dev.	Other Mean	Other St.Dev.	Significance
Schedule delay	0.242	0.258	0.432	0.305	0.098
Cost overrun	0.379	0.405	0.222	0.263	0.246

*Influence of Region.* The influence of the geographical was is not statistically significant (Table 4). The analysis focused just on Europe and Asia, as the number of observations for the other regions are not enough to prove significant. This result was in line with the studies by Flyvbjerg et al. (2003b; 2004) who stated that the cost escalation phenomenon had rather global diffusion, regardless of the region where the infrastructure was delivered. Similar non-significant correlation was also found when it came to analyze national tunnel projects versus transnational projects, such as alpine base tunnels. This indicated that the involvement of multiple governments was not likely to be a predictor of cost and schedule poor performance.

Table 4. Influence of region on project performance

Performance variables	Europe Mean	Europe St.Dev.	Asia Mean	Asia St.Dev.	Significance
Schedule delay	0.370	0.327	0.272	0.245	0.438
Cost overrun	0.317	0.327	0.132	0.123	0.19

*Trends over Time.* In their studies, Flyvbjerg et al. (2003a) could not detect any cost and schedule performance improvements in past projects. However, in recent years, construction technology, as well as project monitoring and control tools have considerably evolved so that one would expect a possible learning curve effect on schedule and cost performance. To understand such project performance trends over time, the sample projects were classified into three clusters according to their start date, referred to as the date the project was formally approved/authorized by government, namely: those started before year 2000, those initiated from 2000 to 2010, and those started after year 2010. The homogeneity of distributions for both schedule delay and cost overrun were measured for both categories using the Kruskal-Wallis test. Results did not prove significant.

However, a significant linear relationship between the project startup year and cost overrun was observed (Figure 1): this means that recent projects have been gaining cost performance improvements. As one would think, the high coefficient of determination ( $R^2$ ) indicates that the project start date is probably not the only one variable that can explain the cost overrun improvement trend (Table 5): the concurrence of other factors was likely to influence the improved cost performance of recent projects, such as, for example, refined project monitoring and control systems.

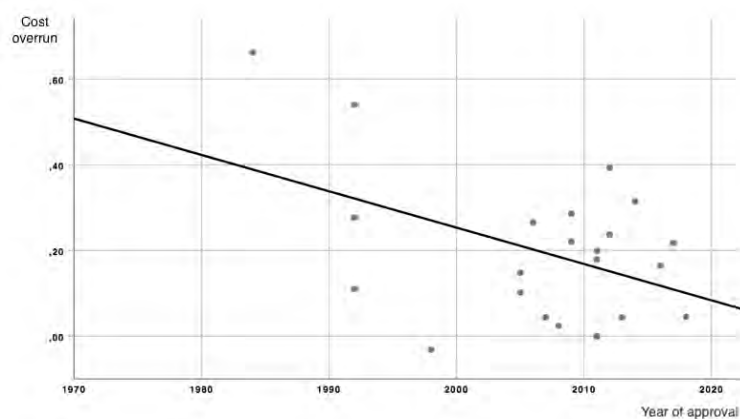


Figure 1. Relation between year of approval and percent cost overrun

Table 5. Linear regression of approval year date versus percent cost overrun

Model Summary						Parameter Estimation	
Equation	$R^2$	$F$	$df1$	$df2$	Significance	$Cost.$	$b_1$
Linear	0.200	5.496	1	22	0.028	17.219	-0.008

*Estimated Project Duration and Budget.* The estimated project duration was also likely to impact on project cost overruns. Intuitively, it was harder to estimate long-term than short-term project budgets. This hypothesis was confirmed by the significant linear relation between the expected duration as the independent variable, expressed in number of years, and the cost overrun dependent variable (Figure 2, Table 6).

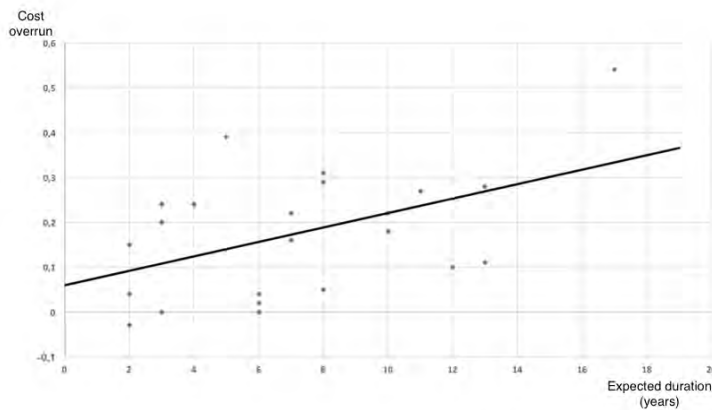


Figure 2. Relation between expected project duration and percent cost overrun

On the contrary, despite intuition that a larger budget could lead to lower project performance, the project budgeted cost did not show any statistically significant impact on schedule delay and cost overrun. However, the cluster of those megaprojects with budgeted cost greater than €4 billion had higher average cost overrun than smaller megaprojects.

Table 6. Linear regression of estimated duration versus percent cost overrun

Model Summary							Parameter Estimation		
Equatio	$R^2$	$F$	$df$	$df$	$df$	Significanc	$Cost.$	$b_1$	
n			1	2	e				
Linear	0.24	6.48	1	21	0.019	0	0.06	0.02	
	0	0				0	0		

### 3.3 The Regression Analysis: The Technical Factors

Some of the technical factors identified in Table 2 proved to have significant relationship with cost overrun, namely the tunnel length, the total length of tunnel tubes, and the number of cross passage tubes (Table 7).

Table 7. Statistical significance of the technical factors on cost overrun

Variable	$R^2$	Significance	Constant	Slope
Infrastructure length	0.016	0.655	0.223	-0.001
Tunnel length	0.393	0.001	0.044	0.007
Total length of tunnel tubes	0.376	0.002	0.077	0.002
Internal diameter of single tube	0.041	0.403	0.067	0.015
Distance between tubes	0.070	0.382	0.094	0.003
Maximum altitude	0.002	0.855	0.191	0.000
Maximum slope	0.034	0.475	0.157	0.002
Number of cross passage tubes	0.517	0.002	0.045	0.002
Distance b/w cross passages	0.047	0.437	0.164	0.000
TBM excavation portion	0.001	0.916	0.186	0.014
Number of Tunnel Boring Machine (TMB) used	0.009	0.749	0.180	0.004
TBM length	0.712	0.001	-0.042	0.001
TBM weight	0.151	0.268	0.083	0.000
TBM diameter	0.039	0.515	0.036	0.017
TBM average speed	0.425	0.016	0.048	0.008
Traditional excavation speed	0.036	0.760	0.344	-0.32
Excavated rock volume	0.000	0.994	0.195	0.000
Excavated rock weight	0.893	0.000	-0.017	0.012

Similarly, Table 8 reports the results of the linear regression analysis and proved no significance of the main technical factors on schedule delay.

Table 8. Statistical significance of the technical factors on schedule delay

Variable	$R^2$	Significance	Constant	Slope
Infrastructure length	0,399	0,007	0,584	-0,005
Tunnel length	0,095	0,126	0,455	-0,005
Total length of tunnel tubes	0,062	0,251	0,415	-0,001
Internal diameter of single tube	0,030	0,453	0,526	-0,023
Distance between tubes	0,054	0,386	0,491	-0,005
Maximum altitude	0,011	0,637	0,319	0,000
Maximum slope	0,024	0,540	0,282	0,003
Number of cross passage tubes	0,062	0,303	0,429	-0,001
Distance b/w cross passages	0,068	0,297	0,402	0,000
TBM excavation portion	0,096	0,197	0,167	0,262
Number of TMB used	0,016	0,642	0,371	-0,008
TBM length	0,125	0,287	0,508	-0,001
TBM weight	0,002	0,890	0,314	0,000
TBM diameter	0,005	0,797	0,434	-0,010
TBM average speed	0,001	0,912	0,349	-0,001
Traditional excavation speed	0,516	0,172	1,316	-0,210
Excavated rock volume	0,117	0,303	0,443	-0,016
Excavated rock weight	0,243	0,600	0,431	-0,005



### 3.3. The Regression Analysis: The Governance Factors

*Influence of Ownership.* Despite expectations, the variables pertinent to the governance model did not result as predictors of cost overrun and schedule delay. In particular, project performance was not likely to be affected if the project was either managed by a governmental body, a public-owned project company, or a privately-financed SPV.

*Influence of Financing Mechanism.* Another influence factor on project performance may be the funding system. However, also there were some differences, on average, they were not significant to explain potential cost overrun or schedule delay between the projects entirely funded by the public sector and privately-financed forms of public-private partnership (PPP) projects (Table 9).

Table 9. Statistical significance of the financing mechanism

Performance variables	Public Mean	Public St.Dev.	PPP Mean	PPP St.Dev.	Significance
Schedule delay	0.333	0.308	0.350	0.263	0.904
Cost overrun	0.264	0.294	0.284	0.376	0.885

*Influence of Contracting Mechanism.* Another factor was the contracting mechanism between the promoter and the contractor: differences between the mean values of separated design versus integrated design contract categories, namely traditional Design-Bid-Build (DBB) infrastructure procurement process versus integrated Design-Build (DB) contracts, proved to have statistical significance on cost overrun. No influence on the schedule delay was observed (Table 10). This can be explained as follows. In a traditional separate DBB delivery system any change to the original design imposes heavy additional charges on the promoter that can lead to substantial scope and budget creeping. Conversely, in an integrated DB or Engineering Procurement Construction (EPC) contract arrangement the final cost increase is likely to be reduced as the cost estimates are made by contractor (Anderson and Oyetunji, 2003).

Table 10. Influence of the separate versus integrated design on project performance

Performance variables	Separate Design Mean	Separate Design St.Dev.	Integrated Design Mean	Integrated Design St.Dev.	Significance
Schedule delay	0.304	0.284	0.420	0.304	0.387
Cost overrun	0.364	0.153	0.361	0.186	0.091

*Influence of O&M Factors.* Finally, the authors investigated the possible implications of O&M practices on project cost and schedule performance. The expected model was that the O&M duty assigned to the same business entity that was involved in the development period could act as an incentive to finish on time and within the budgeted cost so as to maximize the project financial profitability. However, the average differences between situations when O&M was given to the same business entity and those when it was given to a different service provider were not likely to influence neither the cost nor schedule performance (Table 11).

Table 11. Influence of the same versus different O&M business entity on project performance

Performance variables	Same entity mean	Same entity st. dev.	Different entity mean	Different entity st. dev.	Significance
Schedule delay	0.340	0.280	0.410	0.300	0.545
Cost overrun	0.290	0.320	0.240	0.320	0.698

#### 4. Discussion

A specific dataset for tunnel megaprojects did not exist and this paper makes it now available for future research and exploration by scholars in the tunnel engineering and construction fields. Also, this dataset aims at integrating both technical and management data with the purpose of demonstrating that project performance likely results from a combination of proper engineering and managerial decisions, such as the choice of the delivery system.

The results of this study have practical implications for decision makers, public managers, project managers and designers involved in tunnel construction megaprojects. They can take some lessons from this study. In particular, it is shown that one of the main drivers of cost overrun and schedule delay is the complexity of the infrastructure, including the length of the tunnel, the total length of tunnel tubes, number of cross passage tubes, and delivery system. Since the length of the infrastructure and similar technical aspects are often constrained by intrinsic morphology and norms, it becomes essential to improve project delivery. This can come via using integrated Design-Build contract mechanism, such as EPC or BOT, as well as adopting associated suitable project estimating, monitoring and control methodologies and tools to pursue improved time, cost and quality performance goals (Martin et al., 2009; Reilly et al., 2011; Narbaev and De Marco, 2017).

From the point of view of project governance, although not statistically significant, the establishment of a project company or SPV seems to improve the project cost and schedule performance than direct management by government. The results of this work also corroborate the findings of Turner and Xue (2018) who recently noted that, given the complex nature of megaprojects, small changes in the input can lead to disproportionate changes in the output. They noted that time and cost targets defined at the outset of a megaproject construction can have little validity and are not values that can be used to judge success or failure of megaprojects.

Due to the reduced number of available observations, the results obtained cannot be declared of complete statistical significance. However, the aim of this study was to detect reasons and provide possible explanations for delays and cost overrun of large tunnel construction projects rather than to assert exact matches. The limited number of projects was inherently related to worldwide construction of large tunnel infrastructures: it was intentionally decided to analyze megaprojects only, which number is therefore limited in the world.

#### 5. Conclusion

This paper presents an empirical analysis based on a dataset collected via reports and first-hand questionnaires submitted to the project promoters and sponsors of 39 tunnel construction

megaprojects internationally. It examines the statistical influence that the main project, technical and governance factors may have on cost and schedule performance of tunnel projects. Analyses revealed that the most significant factors are those related to the project complexity such as the length of the tunnel, the total length of the tunnel tubes, the number of cross passage tubes, and the type of project delivery. This study reveals that the size and technical design complexity may be crucial variables to explain the cost and schedule underperformances that are typically experienced in tunnel construction megaprojects.

The findings of the current study can be used by construction management scholars to better understand the main factors that may influence the chronic cost overrun and schedule delays of large infrastructure projects. Tunnel construction practitioners can benefit from the research findings in their attempt to help improve the performance of future tunneling megaprojects and making better technical and managerial decisions.

Future research should aim to extend this empirical analysis to smaller tunnel construction projects in order to figure out if size could be also a determinant of project performance. In other words, it would be important to explore whether the size and complexity of the tunnel infrastructure is a peculiar factors of low performance for megaprojects only, which is a main theoretical assumption and conclusion of this study or it indifferently applies to all tunnel sizes. So far, one can conclude that tunnel megaprojects lag behind schedule and overrun cost because of their large size. However, future research may conclude that this is because of the intrinsic nature of tunnel construction projects.

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## **A. Appendix: The Sample of Tunnel Projects**

The data on the following tunnel projects are used in this study: the Sydney Metro Northwest and Southwest&City tunnels in Australia, the Lainzer, Wienerwald, Semmering and Koralm tunnels in Austria, the Agua Negra Tunnel crossing Chile and Argentina, the West Qinling tunnel in the Gansu province of China, the New Guanjiao tunnel in the Chinese province of Qinghai, the Central-Wan Chai Bypass tunnel in Hong Kong, the Toyo and La Linea tunnels in Colombia, the Yulhyeon tunnel in South Korea, the Cityringen metro line in Denmark, the FinEst tunnel link from Finland to Estonia, the Bossler tunnel in Germany, the Fehmarnbelt Link connecting Germany and Denmark, the Seikan tunnel in Japan, the Jaipur Metro Phase 1 and Phase 2 in India, the Italian Terzo Valico, the TELT Moncenisio base tunnel from France and Italy, the Brenner alpine base tunnel from Austria to Italy, the Norwegian projects of Follo Line, Ryfast, Rogfast, and New Ulriken tunnels, the Metro Doha Phase 1 in Qatar, the Guadarrama tunnel in Spain, the Stockholm bypass tunnel in Sweden, the Ceneri, Lötschberg and Gotthard base tunnels in Switzerland, the Eurasia tunnel and the Üsküdar Ümraniye Çekmeköy metro project in Turkey the Channel tunnel from the United Kingdom to France, and the Qamchiq tunnel in Uzbekistan.

# Impact of Project Complexity Factors on Profitability using System Dynamics Modeling

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## Abstract:

Complexity and risks directly influence the profitability of construction projects. Therefore, among other success criteria for construction firms, profitability cannot be improved without managing these project risks. The purpose of this study is to explore interconnection of project complexity factors and their impact on profitability through system dynamics. A comprehensive literature review was carried out in which research papers from highly ranked journals from last twenty years were reviewed. As a result, 98 complexity factors were identified. Out of them, 19 factors were shortlisted based on their frequency and interconnectivity. A co-occurrence matrix of order 19x19 was developed and then five factors having highest co-occurrence were extracted. Finally, an influence matrix of order 5x5 was formed based on which systems thinking diagram with three reinforcing and one balancing loop was developed that lead the system dynamic modelling. The findings can be useful for decision-making of profitability in the complex construction projects. This work is an original attempt to explore the interconnection of project complexity factors for construction projects and their impact on profitability. It may be used for further research and development about the risks associated with the formulated system dynamic model.

**Keywords:** profitability; project complexity; construction projects; interconnection matrix; systems thinking; system dynamics

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## 1. Introduction

Business success is assessed in terms of profitability which is one aspect of financial performance of companies. Profitability is a key goal for all business enterprises and therefore, it becomes important for any firm to review the past and current profitability and focus on future (Khan and Singhal, 2015). Profitability variation has been found across construction industry (Ossman, 2015). The variation is due to the presence of various risk factors. Construction projects are inherently exposed to unpredictable and complicated risk scenarios. (Han et al., 2007a). It is essential to assess risks in construction activities to minimize losses and enhance profitability. The nature of construction activities, complicated processes, challenging environment, organizational structure and many other variables generate various kinds of risk. As a result, construction projects face time delays and cost overruns (Khodeir and Mohamed, 2015). Construction industry becomes more complicated by the involvement of various specialized contractors making construction projects fragmented (Mohan Kumar et al.). Keeping it in view, the assessment of profitability becomes difficult. Investigations are required at early stages to ensure effective planning for construction projects and to prevent failure

(Tamošaitienė et al., 2011). Construction companies do not make as much profit as they estimate at the time of project award. Therefore, a protocol to analyze profitability should be developed to understand the gaps between actual and estimated profits and the origins of loss of profit in construction projects (Tamer et al., 2012). The profitability and success of construction project are correlated with risk variables (Han et al., 2007a). When complexity is more, associated risk management becomes more challenging (Qazi et al., 2016) and it influences profitability (Chang and Leu, 2006). Contractors can enhance their profitability if they could control input resources and improve accuracy of estimation and pricing (Ling and Liu, 2005). It is suggested that it is feasible to estimate a project's profitability before its execution. Key variables in terms of scope and team can best explain the variation in profitability. In project initiation and planning phases, these variables effect the profitability (return on sales) (Chen et al., 2013). Higher risks reduce the profitability of a business overall (Tan and Floros, 2012) and risk-taking behavior of an organization affects its financial performance. For instance, construction organizations which are profitable and successful would place more emphasis on risk factors that affect schedule-cost-quality trio of projects (Ling and Liu, 2005, Tamer et al., 2012).

Additionally, the use of traditional construction techniques, contract types (Isatto et al., 2013), disputes and claims, differing site conditions (Gosling et al., 2012) and unskilled labor overrun the scope of projects (Giannakis and Papadopoulos, 2016). Such issues have serious impact on time, cost and quality which results into dissatisfactory project performance (Albaloushi and Skitmore, 2008, PMI, 2004). However, project performance and quality can be achieved by applying the project complexity management (PCM) approach, which would bring control over the work variations, information flow and project plan accuracy (Vachon and Klassen, 2002, Gosling et al., 2012, Zsidisin et al., 2004, Kim and Nguyen, 2018).

Construction projects also bring complexity through technical drawings, construction processes, specialized tools, plants and equipment, etc. Additionally, these projects are initiated in complex and dynamic environments, resulting in circumstances of high uncertainty and risk that are compounded by demanding time constraints (Mulholland and Christian, 1999).

(Geraldi et al., 2011) posited five dimensions of complexity comprising of structural, uncertainty, dynamics, pace and socio-political. Almost all construction projects have these dimensions of complexity. Dynamics is always a part of construction project complexity specially when it is in execution phase. To handle the dynamics involved in systems, various tools and techniques are available. System Dynamics (SD) is one such method to enhance learning in complex systems and tools that enable a better understanding of the dynamics of a complex system. It can address complexity involving interactive modelling and serve as a tool for representation of feedback structure and simulation. SD was developed by Forrester in 1961 to reflect the view that the dynamics of industrial systems result from underlying structure of flows, delays, information and feedback. Mathematical models of the relations between system components are constructed and computer simulation can help optimize the system.

SD is interdisciplinary, it is grounded in the theory of non-linear dynamics and feedback control developed in mathematics, physics and engineering. These tools are applied to the behavior of human, as well as technical systems. SD draws on cognitive and social psychology, organization theory, economics and other social sciences to solve important real-world

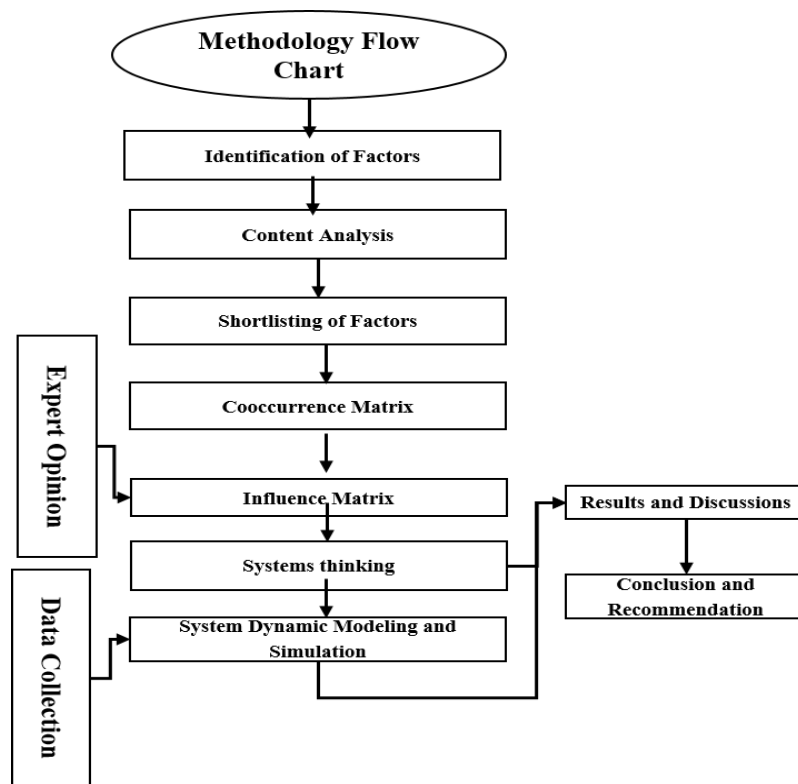
problems. SD approach has the ability to create ‘micro worlds’ that present real-world issues in a manner that is simple, practical, structured and comprehensible. The strength is in the ability to break down complex systems into comprehensible sub-systems. SD addresses complexity and process relationships based on non-linear feedback systems. It can help improve information flow, through collaboration technologies leading to improved productivity.

Therefore, the present study opts to explore the interrelations and connectivity of project complexity factors influencing the construction projects in terms of their co-occurrence. For doing so, significant influencing factors of project complexity are identified and their interrelations and co-occurrence in literature are studied. Further, the frequency of co-occurrence is analyzed, highlighting the level of interrelation between the influencing factors. Thus, the obtained results highlight the up-to-date progress, connotation of research and substantial knowledge gap. The current study will help the professionals and researchers in comprehensive learning of project complexity factors in the construction sector as well as their importance toward profitability. The contribution of this work is to refine body of knowledge and policies relevant to construction project complexity for prediction of profitability. Based on the gaps identified, this research chooses to analyze the existing literature on project complexity factors and to develop a system thinking and system dynamics modelling of these factors.

## **2. Methodology**

Many studies have been conducted on construction projects, in which a variety of factors have been addressed for project complexity. But still improvement is required to enhance construction profit keeping in view the construction project complexity and management. This study considers the literature published on construction during the previous period. The detailed structure of methodology adopted for the study is shown in the Figure 1.





**Figure 8. Flowchart of Methodology**

The core of this synthesis was to analyze the co-occurrence and interconnections of factors from shortlisted articles. For this purpose, in step 1, all the project complexity factors (98) were identified as appeared in the selected articles in different years, out of which, 19 factors have been shown in Table 1. Then, in step 2, those factors were ranked, based on their relative impacts within their respective articles and total frequency (Ahmad et al., 2018, Ullah et al., 2016). For this purpose, qualitative scores of relative impact of factors within literature was assessed on a scale of low to high (top 33.33% factors = High, 5; Middle 33.33% = Medium, 3; Bottom 33.33% factors = Low, 1) and total frequency of each factor was calculated. Further, relative importance index (RII), followed by the cumulative weightage were calculated and 19 factors having cumulative weight above 50% were selected for further analysis as shown in Table 2.

**Table 19. Ranking of Factors Based on Frequency of Occurrence**

S/N	Factors	Frequency	References
1	Design Issues	14	(Han et al., 2007a), (El et al., 2015), (Hashemi et al., 2011), (Qazi et al., 2016), (El-Sayegh and Mansour, 2015), (Kartam and Kartam, 2001), (Zou et al., 2007), (Cheng, 2014), (Long et al., 2004), (El-Sayegh, 2008), (Tang et al., 2007), (Iqbal et al., 2015), (Lu and Yan, 2013), (Andi, 2006)
2	Price Fluctuations	14	(El et al., 2015), (Liu et al., 2016), (Ameyaw and Chan, 2016), (Qazi et al., 2016), (Kartam and Kartam, 2001), (Zou et al., 2007), (Cheng, 2014), (Cheng, 2014), (Enshassi et al., 2009), (El-Sayegh, 2008), (Iqbal et al., 2015), (Lu and Yan, 2013), (Andi, 2006), (Andi, 2006)
3	Shortage of Resources	13	(El et al., 2015), (Hashemi et al., 2011), (Qazi et al., 2016), (El-Sayegh and Mansour, 2015), (Kartam and Kartam, 2001), (Sambasivan and Soon, 2007), (Cheng, 2014), (Enshassi et al., 2009), (Long et al., 2004), (El-Sayegh, 2008), (Assaf and Al-Hejji, 2006), (Iqbal et al., 2015), (Andi, 2006)

4	Planning & Scheduling	12	(El et al., 2015), (Choudhry et al., 2014), (El-Sayegh and Mansour, 2015), (Kartam and Kartam, 2001), (Zou et al., 2007, Long et al., 2004), (Sambasivan and Soon, 2007), (Han et al., 2007b), (Schieg, 2006), (El-Sayegh, 2008), (Assaf and Al-Hejji, 2006), (Iqbal et al., 2015)
5	Contractor's Ability and Experience	11	(Han et al., 2007a), (Liu et al., 2016), (Qazi et al., 2016), (Kartam and Kartam, 2001), (Zou et al., 2007), (Sambasivan and Soon, 2007), (Cheng, 2014), (Enshassi et al., 2009), (Han et al., 2007b), (Long et al., 2004), (Andi, 2006)
6	Lack of Co-ordination and Communication	10	(Han et al., 2007a), (Hashemi et al., 2011), (El-Sayegh and Mansour, 2015), (Kartam and Kartam, 2001), (Hwang and Ng, 2016), (Sambasivan and Soon, 2007), (Cheng, 2014), (Schieg, 2006), (Lu and Yan, 2013), (Pheng and Chuan, 2006)
7	Payment Delays	10	(El et al., 2015), (Hashemi et al., 2011), (Fang et al., 2004), (Ameyaw and Chan, 2016), (El-Sayegh and Mansour, 2015), (Kartam and Kartam, 2001), (Han et al., 2007b), (Ling and Hoi, 2006), (Assaf and Al-Hejji, 2006), (Iqbal et al., 2015)
8	Safety Rules & Measures	8	(El et al., 2015), (Hashemi et al., 2011), (El-Sayegh and Mansour, 2015), (Kartam and Kartam, 2001), (Zou et al., 2007), (Tang et al., 2007), (Iqbal et al., 2015), (Lu and Yan, 2013)
9	Quality of Work	7	(El et al., 2015), (Liu et al., 2016), (Qazi et al., 2016), (Kartam and Kartam, 2001), (Cheng, 2014), (Tang et al., 2007), (Lu and Yan, 2013)
10	Contract Related Problems	7	(Han et al., 2007a), (El et al., 2015), (Qazi et al., 2016), (Adams, 2006), (Han et al., 2007b), (Long et al., 2004), (Lu and Yan, 2013)
11	Condition of Host Country	7	(Han et al., 2007a), (Liu et al., 2016), (Kartam and Kartam, 2001), (Zou et al., 2007), (Han et al., 2007b), (Long et al., 2004), (Lu and Yan, 2013)
12	Supplier Issues	7	(El et al., 2015), (Qazi et al., 2016), (Zou et al., 2007), (Sambasivan and Soon, 2007), (El-Sayegh, 2008), (Iqbal et al., 2015), (Pheng and Chuan, 2006)
13	Poor Site Management & Supervision	7	(Hashemi et al., 2011), (Fang et al., 2004), (Choudhry et al., 2014), (Sambasivan and Soon, 2007), (Long et al., 2004), (El-Sayegh, 2008), (Assaf and Al-Hejji, 2006)
14	Interruptions & Changes During Construction	7	(Fang et al., 2004), (Qazi et al., 2016), (Kartam and Kartam, 2001), (Enshassi et al., 2009), (Long et al., 2004), (El-Sayegh, 2008), (Assaf and Al-Hejji, 2006)
15	Funding Problems	6	(El et al., 2015), (Choudhry et al., 2014), (Kartam and Kartam, 2001), (Zou et al., 2007), (Han et al., 2007b), (Iqbal et al., 2015), (Lu and Yan, 2013)
16	Financial Difficulties	6	(Choudhry et al., 2014), (Zou et al., 2007), (Long et al., 2004), (Tang et al., 2007), (Assaf and Al-Hejji, 2006)
17	Technology Issues	5	(El et al., 2015), (Hashemi et al., 2011), (Fang et al., 2004), (Schieg, 2006), (Long et al., 2004)
18	Time Management	4	(Qazi et al., 2016), (Cheng, 2014), (Schieg, 2006), (Pheng and Chuan, 2006)
19	Lack of Qualified Professionals	4	(Long et al., 2004), (El-Sayegh, 2008), (Lu and Yan, 2013), (Andi, 2006)

**Table 20. Ranking of Factors Based on Scoring and Importance Index**

S/N	Factors	Frequency	High	Medium	Low	Selected Rank	Qualitative Score by Likert's Scale (1-5)	Importance Index	Individual Score	Cumulative Score
1	Planning & Scheduling	12	6	5	1	High	5	0.4000	0.05445	0.0544
2	Design Issues	14	5	8	1	Medium	3	0.2800	0.03811	0.0926
3	Price Fluctuations	14	4	7	3	Medium	3	0.2800	0.03811	0.1307
4	Shortage of Resources	13	3	5	5	Medium	3	0.2600	0.03539	0.1661
5	Quality of Work	7	3	2	2	High	5	0.2333	0.03176	0.1978
6	Contractor's Ability and Experience	11	3	6	2	Medium	3	0.2200	0.02995	0.2278
7	Lack of Co-ordination and Communication	10	2	5	3	Medium	3	0.2000	0.02722	0.2550
8	Payment Delays	10	2	5	3	Medium	3	0.2000	0.02722	0.2822
9	Funding Problems	6	5	1	0	High	5	0.2000	0.02722	0.3094
10	Financial Difficulties	6	4	1	1	High	5	0.2000	0.02722	0.3367
11	Technology Issues	5	2	2	1	High	5	0.1667	0.02269	0.3593
12	Safety Rules & Measures	8	1	4	3	Medium	3	0.1600	0.02178	0.3811
13	Contract Related Problems	7	2	4	1	Medium	3	0.1400	0.01906	0.4002
14	Condition of Host Country	7	2	3	2	Medium	3	0.1400	0.01906	0.4192
15	Supplier Issues	7	0	4	3	Medium	3	0.1400	0.01906	0.4383
16	Poor Site Management & Supervision	7	3	4	0	Medium	3	0.1400	0.01906	0.4574
17	Interruptions & Changes During Construction	7	2	4	1	Medium	3	0.1400	0.01906	0.4764
18	Time Management	4	2	2	0	High	5	0.1333	0.01815	0.4946
19	Lack of Qualified Professionals	4	2	1	1	High	5	0.1333	0.01815	0.5127

A cross-sectional content analysis of the shortlisted factors was performed to establish the co-occurrence matrix, where each value in matrix represents the frequency of co-existence with other factors. For example, in how many articles, 'Financial Difficulties' and 'Price Fluctuation' factors have been found together? The result of this analysis in the form of co-occurrence matrix highlights the interconnection among the factors.

Based on the interconnection found, expert opinion has been taken from field and academic professionals having experience of 12 years or more at data collection stage-I. The experts were asked to find the influence of factor Financial Difficulties ( $i$ ) on Price Fluctuations ( $j$ ). Whether the influence exists 'Yes' or 'No'? If  $i$  influences  $j$ , then the type of influence was also elaborated in the form of positive or negative with the numerical value. The scale used ranges from 1 to 5 (1 = low influence and 5 = high influence). Finally, the relationship, value and polarity have been determined. For example, factor Financial Difficulties ( $i$ ) is influenced by Price Fluctuations ( $j$ ), the relationship is 'Yes', value is '3.56' and polarity is 'Positive'. The influences of all selected factors were calculated in this way. Finally, the influence matrix was developed which serves as a tool for systems thinking. In systems thinking, causal relationship diagram of variables influencing construction project complexity, balancing feedback and reinforcing loops were developed. Systems thinking was done using VENSIM® software. Based on systems thinking and developed influence matrix, data was collected in stage-II. The systems thinking was converted to stock and flow diagram. Further, the system dynamic modelling was done and equations were developed for project complexity and profitability.

### 3. Results and Discussions

#### 3.1 Co-occurrence Matrix

The detail review of selected literature resulted into identification of total 98 factors affecting project complexity. Following the previously explained methodology, top 19 factors having a cumulative score of over 50% were shortlisted. Further, the frequency of co-occurrence was determined for the formulation of co-occurrence matrix. To establish the cross-sectional matrix, co-occurrence of all the factors with each other was analyzed such that how many times two factors have been cited together in the literature. For example, *financial difficulties* and *price fluctuations* appeared together in six articles. By doing so, a 19x19 matrix having 310 points of co-occurrence between all the project complexity factors is established, as shown in Table 3.

**Table 21. Cooccurrence Matrix**

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	No. of Co-occurrences	Highest co-occurrence
F1	1	0	0	0	3	2	0	0	1	1	0	4	4	1	2	1	0	1	0	10	4
F2	0	1	1	2	2	3	4	4	1	2	3	4	2	1	2	5	3	2	3	17	5
F3	0	1	1	1	0	1	3	1	2	2	2	1	1	0	1	2	0	2	2	14	3
F4	0	2	1	1	2	4	2	1	1	2	2	4	2	4	3	1	2	2	1	17	4
F5	3	2	0	2	1	5	1	0	0	1	2	5	6	4	3	2	1	2	1	15	6
F6	2	3	1	4	5	1	2	1	3	3	3	6	5	3	5	2	1	3	2	18	6
F7	0	4	3	2	1	2	1	3	2	2	2	2	1	0	1	4	2	2	3	16	4
F8	0	4	1	1	0	1	3	1	1	1	2	2	1	0	2	4	2	1	2	15	4
F9	1	1	2	1	0	3	2	1	1	4	1	3	1	1	2	1	0	2	1	16	4
F10	1	2	2	2	1	3	2	1	4	1	3	5	2	3	3	3	2	2	3	18	5
F11	0	3	2	2	2	3	2	2	1	3	1	4	4	2	3	4	1	3	4	17	4
F12	4	4	1	4	5	6	2	2	3	5	4	1	6	5	6	5	2	4	2	18	6
F13	4	2	1	2	6	5	1	1	1	2	4	6	1	4	4	3	1	4	3	18	6
F14	1	1	0	4	4	3	0	0	1	3	2	5	4	1	2	3	3	2	1	15	5
F15	2	2	1	3	3	5	1	2	2	3	3	6	4	2	1	2	1	2	1	18	6
F16	1	5	2	1	2	2	4	4	1	3	4	5	3	3	2	1	3	2	4	18	5
F17	0	3	0	2	1	1	2	2	0	2	1	2	1	3	1	3	1	1	2	15	3
F18	1	2	2	2	2	3	2	1	2	2	3	4	4	2	2	2	1	1	2	18	4
F19	0	3	2	1	1	2	3	2	1	3	4	2	3	1	1	4	2	2	1	17	4
																				310	

F1: Condition of Host Country; F2: Contract Related Problems; F3: Contractor's Ability and Experience; F4: Design Issues; F5: Financial Difficulties; F6: Funding Problems; F7: Interruptions & Changes During Construction; F8: Lack of Co-ordination and Communication; F9: Lack of Qualified Professionals; F10: Payment Delays; F11: Planning & Scheduling; F12: Poor Site Management & Supervision; F13: Price Fluctuations; F14: Quality of Work; F15: Safety Rules & Measures; F16: Shortage of Resources; F17: Supplier Issues; F18: Technology Issues; F19: Time Management

The results reveal that, five factors *Poor Site Management & Supervision*, *Price Fluctuations*, *Safety Rules & Measures*, *Funding Problems* and *Financial Difficulties* have maximum frequency of cooccurrence (6). Also, their number of connections are 18, 18, 18, 18 and 15 respectively. These five factors were considered for expert opinion to develop the influence matrix.

### 3.2 Influence Matrix

The influence matrix confirms influential relationships of the selected factors as shown in Table 4. The impact of each influence was solicited from the experts which was then averaged and normalized for input into the SD model. The field professionals confirmed a total of 55 relationships out of 60. The diagonals show the influence of similar factors are identity. The normalized impact score with polarity values are shown for the developed influence matrix. The results reveal that all the factors have strong influence over each other except the relationship of price fluctuations does not confirm the implementation of safety rules and measures in construction projects. Further, the price fluctuations slow down the management at site because of the delayed procurement process.

**Table 4: Influence Matrix**

Influence Matrix	Financial Difficulties	Price Fluctuations	Funding Problems	Poor Site Management & Supervision)	Safety Rules & Measures
Financial Difficulties	1.00	0.712	0.636	0.642	0.760
Price Fluctuations		1.00	0.616	-0.584	
Funding Problems			1.00	0.542	0.460
Poor Site Management & Supervision)				1.00	0.662
Safety Rules & Measures					1.00

### 3.3 Systems Thinking

Many problems in construction industry are complex in terms of technology, pace, social and human elements (Van der Lei et al., 2011). These issues are the main source to hit cost, quality, time and scope (Dangerfield et al., 2010, PMI, 2004). Systems diagram serves as a structure and provides the conceptualization of complex problems (Khan et al., 2016). Through systems diagram, identification of issues and concerned factors are highlighted and solved systematically (Dangerfield et al., 2010, Khanzadi et al., 2012). Systems diagram is used to study main and sub systems, and key factors which are interconnected and have influences within a systems diagram (Oehmen et al., 2009, Ghadge et al., 2013). Keeping in view the construction projects' complexity and concerned profitability, systems diagrams plays a vital role (Qazi et al., 2018). Interdependency of factors in project complexity by using this technique was analyzed by various researchers (Nishat Faisal et al., 2006, Pfohl et al., 2011). A systems diagram is generated based on the influence matrix. The pictorial view of the systems diagram of the project complexity factors which are sources to fluctuate profitability is shown in Figure 2.

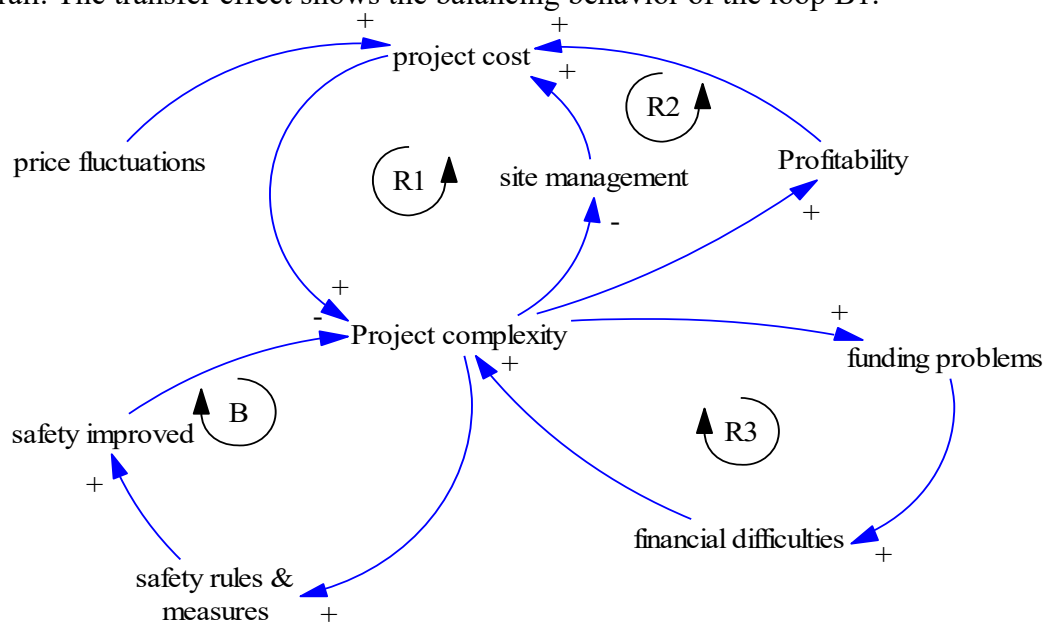
The diagram reveals that there are three reinforcing loops and one balancing loop along with one exogenous variable. It disturbs the impact of all variables in association either they are in reinforcing loops (R1, R2 and R3) or in balancing loop (B1).

The reinforcing loop R1 describes the fact that with price fluctuation, project cost increases. This increased project cost generates project cost complexity, further to slow down and disturb the site management. By the end, project cost will further increase because more money must be spent to manage the site effectively. The transfer of effect results into overall increase of the loop R1.

The second reinforcing loop R2 shows that with the increase of project complexity, more advance technologies should be used. More consumption of technology ensures the ease in construction and enhance profit margins. Finally, the project cost will be more, which explain the increased effect of the reinforcing loop R2.

The third reinforcing loop R3 explain that by the increase in project complexity, the chances of increase in financial cost of the project are elevated. It will require more funds and create funding issues leading to financial difficulties of the project. The effect transfer in the form of more project complexity shows the reinforcing behavior of the loop.

The systems thinking contains one balancing loop B1. Project complexity increases the difficulties in construction operations and to smooth the construction process, proper implementation of safety rules and measure at site are necessary. Application of tight safety rules ensures the improvement in the safety mechanisms and reduced chances of mishaps. Finally, the construction operation will be smooth and project complexity will be reduced overall. The transfer effect shows the balancing behavior of the loop B1.

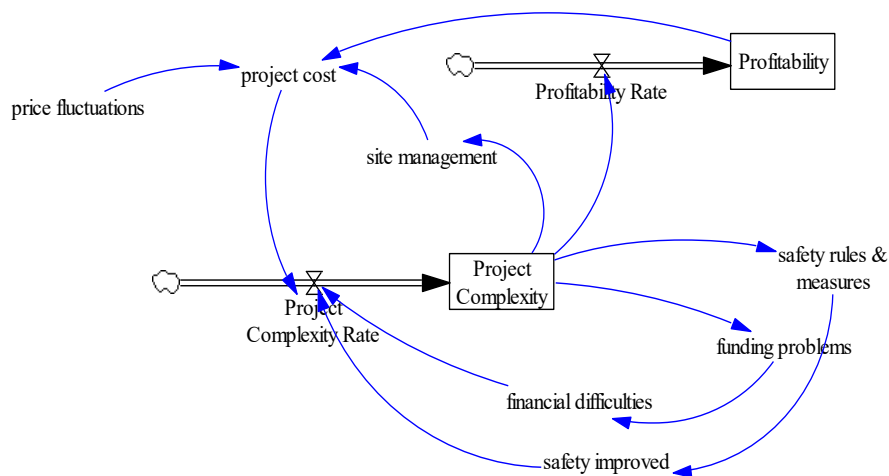


**Figure 9. Systems thinking diagram of balancing and reinforcing loops**

### 3.4 System Dynamic Modelling

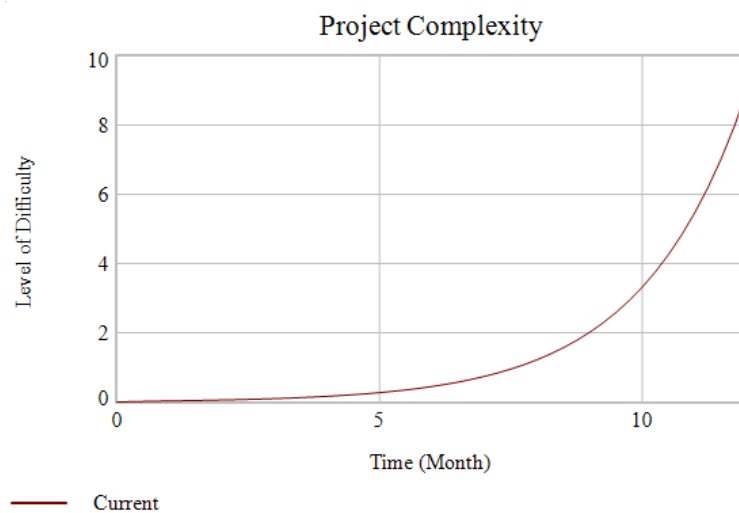
The developed systems thinking is first converted into stock and flow diagram. The stock and flow diagram and data collection in stage-II from field professionals with Cronbach alpha

value 0.853 were used for system dynamic modelling. The non-linearity of the variables is judged for the problem in construction projects. The pictorial view of system dynamic modelling is shown in Figure 3.



**Figure 10. System dynamic modelling**

The simulation represents the time behavior of system about construction project complexity and profitability over the period of 12 months. The simulation is done for two specific stocks such as project complexity and profitability. In the first, project complexity simulation result shows that it is an increasing function. Project complexity is zero at start and it increases exponentially to a maximum value of 9% over the period of 12 months as shown in Figure 4. This non-linearity is due to the feedback impact of other variables in the system.



**Figure 4: Dynamic Behavior of Project Complexity w. r. t. Level of Difficulty Over Time**

The second simulation is done for the second stock profitability. The graph obtained by the simulation shows that the profitability reaches to the maximum value of 15% for the same period of 12 months. This also confirms the relationship that with 9% increase in project complexity results into 15% increase in profitability for the same period as shown in Figure 5. The increase in project complexity demands the use of more modern technology, since by 9%



project complexity, profitability is 15% which verifies the exponential growth. The combined scenario for the both stocks is presented in Figure 6.

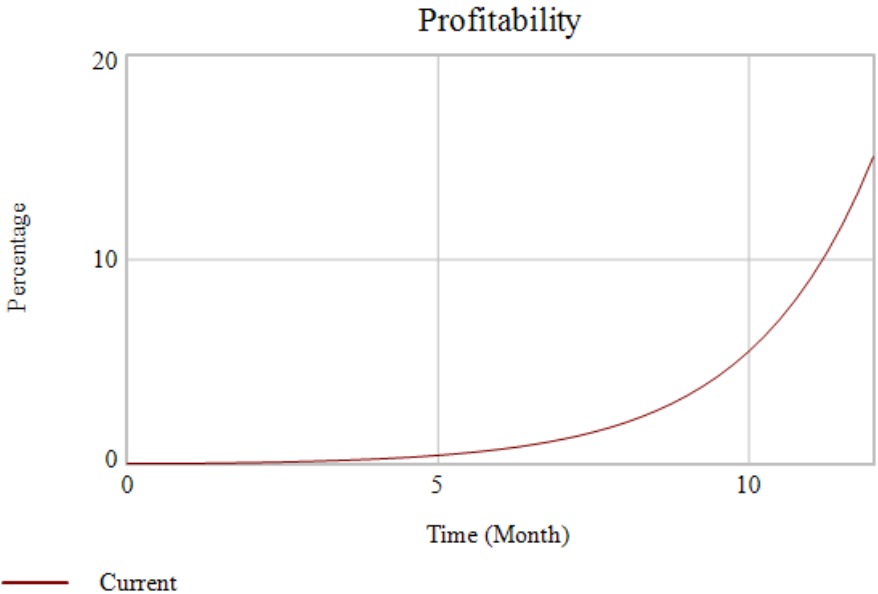


Figure 11. Dynamic Behavior of Profitability Over Time

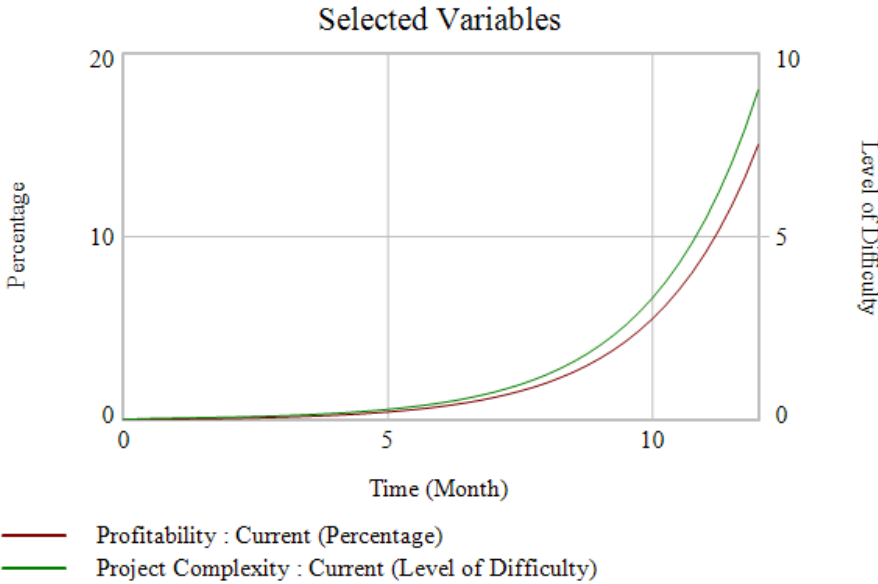


Figure 12. Dynamic relationship between Profitability and Project Complexity

4. Conclusions

Project complexity and risks are directly interconnected with profitability of construction projects since they are inherently exposed to unpredictable and complicated risk scenarios. To get maximum benefits from projects, a protocol to analyze profitability has been developed to understand the gaps between actual and estimated profit and the origins of loss of profit in

construction projects. The results of this study show that the highest frequencies are observed for *design issues* (14) and *price fluctuations* (14). The factors *time management* (4) and *lack of qualified professional* (4) are observed less. The importance index is maximum for *planning & scheduling issues* and minimum are for *time management* and *lack of qualified professionals*. In the co-occurrence matrix, the maximum values are 18 for *funding problems, payment delays, poor site management & supervisions, price fluctuations, safety rules & measures, shortage of resources* and *technology issues*.

The results also conclude that the highest frequencies of cooccurrence is 6 for the factors *financial difficulties, funding problems, poor site management & supervision, price fluctuation* and *safety rules & measure*. This study also concludes that these factors are the backbone of complexity in construction projects to predict the profitability. The minimum frequencies of cooccurrences are observed for *supplier issues* and *contractor's ability and experience*. Furthermore, the system thinking model shows three reinforcing (R1, R2, R3) and one balancing loops (B1) for project complexity. Further, the simulation result reveals that for 9% project difficulty level for complexity generates 15% profitability, which is an exponential growth. The main reason to get more profit is the smoothness of construction processes due to adoption of more advanced technology. More use of technology as resources enhance the profits in construction project.

Based on the results, it is recommended that the factors explored should be handled carefully in construction projects. These factors may enhance project complexity and hinder the success of construction projects in terms of their overall profit, cost, quality, time and scope. Proper mechanisms should be developed from start to end to handle project complexity. These parameters can be used as a checklist for the implementation of a construction project. Risk concerned with these factors can be identified from literature and data can be collected to make a risk-based model as future agenda. The practical implications of this study are that it helps to forecast and improve the profit margin in construction project as the level of difficulty increases during construction phases and for decision-making of profitability in the complex construction projects through effective project complexity management. Project complexities are managed using modern technology and management techniques. Project management knowledge areas are very beneficial in this regard.

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# Hindrances to Complete BIM Utilization in the South African Construction Industry: A Preliminary Study

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## **Abstract:**

This paper presents the results of a preliminary study conducted to determine the hindrances to the complete utilization of BIM features in the delivery of construction services in South Africa. The study conducted a questionnaire survey among construction professionals in Gauteng province, South Africa. Data gathered were analyzed using percentage, mean item score and Kruskal-Wallis H-test. The reliability of the questionnaire was also determined using Cronbach-alpha test. This study shows that the major hindrances are training and software costs increment, organizational culture change, lack of enough employee training and revise workflow, and a lot of possible legal problems.

*Keywords: BIM; hindrances; innovation; South Africa; construction industry*

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## **1. Introduction**

The construction industry worldwide aims at achieving value for money, cost and time through technological innovations. Modelling based Information and Communication Technology (ICT) simulations, and Building Information Modelling (BIM) based ICT (Adwan and Al-Soufi, 2018) are among such innovations. The building Information model is an Information and communication technology concept that is for achieving a construction project right from the inception stage to the in-use stage. However, on a global scale, the construction industry faces some hindrances in the use of this innovation. Hindrances to the application of BIM are categorized into a procedure, technology and people factor (Rekola, Kojima and Mäkeläinen, 2010; Succar, Sher and Williams, 2012).

These three categories are common in developed and developing nations. Love, Irani and Edwards (2004) describes that investment cost is a threat to innovation adoption. Barlish and Sullivan (2012) stated that understanding of the technology is another major threat. This is because the scope and definition of BIM are either too broad or unclear (Succar, 2009). As a result, confusion occurs among users (Succar, 2009). This confusion poses a rejection threat by industry practitioners as organizational culture is a difficulty to bend to this innovation (Mitchell and Demian, 2011). There is also a problem of BIM acceptance (Lee, Yu and Jeong, 2013). In general, these barriers are potential threats to BIM adoption. The main purpose of this study is to address the hindrances to complete utilization of BIM features in South African construction industry. This knowledge will help better delivery of construction services in South Africa. The subsequent part of this study reviewed related literature, discussed the methodology used, results gathered from the study then led to a conclusion.

## 2. Literature Review

Numerous studies have been conducted to outline the benefits of BIM. Interoperability is one of the benefits (Rekola, Kojima and Mäkeläinen, 2010; Singh, Gu and Wang, 2011). However, these benefits are not applicative in some instances. For example, it is very difficult to synthesize the skills of various construction disciplines (Manderson, Jefferies and Brewer, 2015). Cost of implementation of BIM technology may also be expensive (Olatunji, 2011). These problems are encountered by both public and private sector. Private sectors of South African construction are mainly Small and Medium Enterprises (SMEs). Hence, investments into BIM technology and lack of consistent guide are particularly encountered by the private sector (Wong, Wong and Nadeem, 2009; Rekola, Kojima and Mäkeläinen, 2010). Therefore, it occurs that guideline for the use of this innovation revolves around its adoption.

The activity of the construction industry is governed by standards. BIM implementation has also been sabotaged by type of contracts used. For instance, the International Federation of Consulting Engineers (FIDIC), Joint Building Contracts Committee (JBCC PBA) and New Engineering settlement (NEC), are some standards that govern the use of BIM. These standards are not too simple for BIM users to apply (Manderson, Jefferies and Brewer, 2015). This makes procurement and management of contract difficult. Thus, the procurement and management of creation contracts potentially turn out to be significant challenges with respect to people, technology, and process (Gu and London, 2010). Consistency is required in the type of contract attached to BIM complete utilization. This will make the many numerous aims of BIM justified.

Literature points out BIM barriers are categorized into style, technology, and people. This is supported by the study of (Olatunji, 2011). Developing countries like South Africa have a small market for construction activities compared to their developed counterpart. The smaller the market the bigger the obstacles to BIM, and vice versa. For example, in South Africa, construction companies are small and feature limited resources to achieve and maintaining BIM software tools (Migilinskas *et al.*, 2013). However, irrespective of size the market and company size, the Architectural, Engineering and Construction (AEC) industry needed to improve its workplace behaviors (Migilinskas *et al.*, 2013). This includes work practices, workers' strengths, company-client relationship, and cultural variation. These can be done by overcoming cultural barriers, supply chain buy-in, Staff Resistance to ICT Literacy, and cost of investment (Azhar, 2011; Mitchell and Demian, 2011; Race, 2013). The goal is to achieve improved accuracy, consistency, integration, coordination and organization. These are all applicable to challenges to BIM adoption in developed and developing countries (e.g. South African Construction Industry).

## 3. Methodology

This study employed a quantitative approach to address the hindrances to the complete utilization of BIM features in the delivery of construction services in South Africa. The study population comprised of construction professionals in Gauteng province, South Africa. The construction professionals were seasoned professionals with experience ranging from less than five years to above twenty years. They were mainly Quantity Surveyors, Architects, Mechanical Engineers, Industrial Engineers, Construction Project Manager, Construction Manager, and

Architect. These professionals were also grouped under contractors, consultants, and government workers. A total of 55 participants took part in the survey.

The study adopted a questionnaire as the instrument for data collection due to its ability to provide a standardized opinion of subjects (Brace, 2005). The questionnaire for the study was designed in two sections. The first section gathered biographical information of the respondents. The second section harnessed information on hindrances to the complete utilization of BIM features in the delivery of construction services in South Africa. A five-level Likert scale was used for scaling responses in this section. 1 represents Strongly Disagree, 2 is Disagree, 3 is Neutral, 4 stands for Agree while 5 is Strongly Agree.

In analyzing the data gathered, a percentage was used for the background information of the respondents while Mean Item Score (MIS) was used to rank the different barrier variables. An MIS value above 3.0 will be focused on as it will show the significant variables. Kruskal-Wallis H test was conducted to check the consistency in the opinion of the group of respondents. Pallant (2016) describes that this non-parametric test is appropriate for testing the significant difference or relationship existing in the view of two or more groups of respondents. The internal consistency of the questionnaire used was also tested using the Cronbach's alpha test whose values range between 0 and 1, and the higher value, the higher degree of internal consistency. The Cronbach's alpha value of 0.743 was derived for the different barrier variables as the derived value tends to 1.0, the questionnaire is reliable.

## **4. Results and Discussion**

### *4.1 Descriptive statistics of the population*

Analysis of biographical data of respondents shows that there are 55% male and 45% female. The construction professionals were 24% Quantity Surveyors, 18% Mechanical Engineers, 9% Industrial Engineer, 7% Electrical Engineer, 7% Construction Project Managers, 16% Construction Managers, 24% Civil Engineers, and 6% Architects. The professionals were categorized under government workers (25% of the population), contractors (40%) and consultants (35%). They had educational qualifications of 7% Doctorate degree, 13% Master's degree, 15% of them have Honors, 36% Bachelor's degree, and 29% National Diplomas holders. These respondents all met the years of work experience required.

### *4.2 Barriers to BIM adoption in the South African Construction Industry*

Table 1 represents analysis showing shows the mean score, chi-square value and significant p-value derived from Kruskal-Wallis H-test for the variables serving as hindrances. Kruskal-Wallis H-test was used to ascertain if there is a significant difference in the view of the category of professionals (Contractor, Consultant and those working for the government). This result depicts that at 95% confidence intervals, there is no significant difference in the view these professionals (p-value 0.05) as all the assessed variables have a significant p-value of above 0.05 except Training and software cost increment with a p-value of 0.033. Therefore, the result from the mean score can be upheld as just one variation exists in the opinion of the respondents.



Table 1 Hindrances to BIM implementation

Variables	MIS	Rank	Chi-Square	P-value
Training and software cost increment	4.15	1	6.826	0.033
Organizational culture change	4.07	2	2.226	0.329
Lack of enough employee training and revise workflow	4.02	3	1.329	0.515
A lot of possible legal problems	4.00	4	0.201	0.904
The notion that BIM is not always relevant to the project on hand	3.95	5	1.422	0.491
Lack of client demand	3.95	5	3.890	0.143
Lack of standard BIM controlling documents	3.85	7	3.783	0.151
Users do not understand the technology	3.84	8	0.969	0.616
BIM skills are too broad and unclear	3.84	8	0.969	0.664
Resistance to change	3.82	10	0.969	0.935
Less knowledge on how to adopt BIM	3.76	11	1.023	0.600
Difficult to align with construction contracts	3.67	12	0.302	0.860
Absence of supply chain buy-in	3.56	13	1.829	0.401

The result from the analysis had the variables ranked according to their mean score. All the variables have mean value above 3.0. This shows all the assessed variables significantly hindered BIM implementation in the South African Construction Industry. However, the most significant hindrances to the complete utilization of BIM features in the delivery of construction services in South Africa are training and software cost increment, organizational culture change, lack of enough employee training and revise workflow and lot of possible legal problems. They have MIS of 4.15, 4.07, 4.02 and 4.00 respectively.

The result of the cost of training staff for the innovation and procuring the software is expensive. South Africa a developing economy is mostly saturated by small and medium enterprises (SMEs). The financial status of construction companies in this group will hinder the expensive training of Staff. This reduces investment for construction innovation idea in developing counties is low (Alshawi *et al.*, 2010) . Also for BIM, SMEs believe the investment-profit ratio is low (Love, Irani and Edwards, 2004) . This agrees with (Azhar, 2011; Migilinskas *et al.*, 2013; Race, 2013) that cost of investment through training and software cost impedes BIM implementation.

Also, organizational cultural change impedes complete BIM utilization in the South African construction industry. Organizational culture is described as the various beliefs, principles, assumption and norms shared by the members of an organization (Huo, 2012). Similarly, organizational culture arises when concepts like changes, growth and merging arise in an enterprise (Khosrowshahi and Arayici, 2012), which influence business the process, people, and technology. Therefore its effect can either be positive or negative towards the adoption of an innovation. Studies have described that corporate or group culture (Owen *et al.*, 2010; Voordijk, 2019), and development culture (Porter, 2019) are most prevalent organizational culture types. These types of organizational change affect BIM usage and how the user's transition to the new method it presents to the workplace.

(Succar, Sher and Williams, 2012) opined that barriers to innovation adoption are people, technology, and process oriented. In order to be innovative organizational culture needs to answer to technology, process, and people. Organization cultural change could solve problems

for an innovative purpose if it is planned ahead and well managed (Schein, 2010). However, this contradicts (Ogbonna and Wilkinson, 2003) that organizational cultural change even when planned could be very difficult to enforce in an organization. This is because organizational culture affects staff differently in an organization. These findings agree with Rekola, Kojima and Mäkeläinen (2010); Mitchell and Demian (2011); and Migilinskas *et al.*, (2013), that organizational cultural change affects BIM utilization around the world. In addition, the culture of distrust, and not willing to share BIM information with allied construction stakeholders relates to organizational culture hindrance to BIM utilization (Stanley and Thurnell, 2014).

The possible legal and contractual problem is another hindrance to full BIM utilization in South African's Construction industry. Evidence gathered from literature revealed that common legal and contractual problems to BIM utilization include design and interoperability errors (Larson and Golden, 2007) and problems to contractual principles (Glover, 2012). Other studies support that and copyrighted data sharing, standardization problems, litigation and protocols, schedule of deliverables interoperability problems are also prevalent legal problems to BIM utilization (Eadie, McLernon and Patton, 2015; Jo *et al.*, 2018). These summarize that BIM users are threatened that design, means of execution of projects and information of projects Smith (2013), will be at a disadvantage through legal and contractual problems.

Olatunji (2011) opined that a legal framework is necessary for innovation like BIM. A framework will reduce the occurrences of negative coordination, and errors and risks related to traditional contractual arrangements (Porwal and Hewage, 2013). However, the framework used in developed countries like the United Kingdom will not fit into that of a developing country like South Africa. This is due to the different maturity level of BIM in the regions (Succar, 2009). In contrast, frameworks are vital tools for BIM implementation, yet are still faced with non-coherent guidelines and difficulty in aligning BIM with construction contracts (Succar, 2009). This agrees with the findings of Gu and London (2010); Olatunji (2011); Porwal and Hewage (2013) that innovation like BIM faces legal problems in its implementation, especially in developing countries.

## **5. Conclusion**

This study addressed the hindrances to the complete utilization of BIM features in the delivery of construction services in South Africa. Using a quantitative approach, the study identified major hindrances to full BIM implementation in the South African construction industry. Upon these findings, the study concludes that the major hindrances are training and software costs increment, organizational culture change, lack of enough employee training and revise workflow, and a lot of possible legal problems. It is, therefore, important to address measures propose measures on how to proceed, leaning on various models such as BIM maturity model or step-wise implementation of BIM.

In addition, the study recommends that proper enlightenment should be given to concerned stakeholders on the investment-profit ratio of BIM. This can be done by proper employee training and government sensitization. Also, there should be an openness to new innovation as it affects organizational culture. Legal problems arising from BIM use can be solved by the government and concerned bodies. This can be achieved on the region's maturity level on BIM

use. This study also recommends that further research is done on strategies to overcome these hindrances especially on the different degrees of BIM use.

This study has been able to contribute to the body of knowledge by identifying factors that hinder complete BIM utilization in construction activities in South Africa. A proper consideration of the findings and recommendation will contribute to BIM utilization within the country. However, this study is limited by the study approach used. It is suggested that a mixed-method approach be used for further studies. The qualitative approach should interview pertinent core construction professionals, in order to tackle the problems in-depth and to prioritise them.

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# Application of Genetic Algorithm for Scheduling Delivery and Dispatching Sequence of Ready Mixed Concrete for Commercial Batching Plants in India

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## Abstract:

Systematic model of delivering ready-mixed concrete becomes a prime factor for the developing infrastructure sectors like India. Generally, the commercial Ready Mixed Concrete (RMC) plant operators have limited numbers of transit mixers to facilitate the increasing demand from different construction sites. Hence there is a need to develop the ultimate dispatching schedule that minimizes the total waiting duration of RMC trucks at construction sites and increases the productivity of plant as well as sites. This paper aims at developing a systematic model of delivering RMC that optimizes the schedule of dispatching RMC transit mixers. This optimization model has been developed based on Genetic Algorithm (GA) that minimizes the total waiting duration of the RMC truck-mixers. This optimized dispatching sequence would reduce the waiting of the truck-mixer at the site for dispatching the concrete and also the site need not wait for the truck-mixer for the concrete to be delivered. The results of the optimization model reveals the optimized delivery sequence for one commercial RMC batching plant and three construction sites codified as site 1, 2 and 3. The results also reveal that for improved and effective delivery of RMC the number of transit-mixers delivering concrete should be increased from six to eight.

*Keywords: batching plants; commercial; dispatching sequence; genetic algorithm; ready mixed concrete.*

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## 1. Introduction

Ready Mixed Concrete (RMC) was introduced into the construction industry in the early twentieth century and has been ever since widely employed. Because of the rapid hardening characteristics of the concrete, Transit Mixers were developed for caring RMC to remote construction sites. Effectively and efficiently delivering RMC to construction sites is an important task to the RMC batching plant authorities. The RMC batch plant operator has to take into account time and flexibility to create an effective dispatching schedule of RMC transit-mixers, that balances the operations at the construction project sites and the batching plant. Genetic algorithm (GA) was invented by Holland (1992) in the early 1970s and since then they have been applied to a large number of complex search problems. Holland's attempt was to emulate the process of natural selection in a search procedure. To that purpose, he showed that complex structures can be encoded using simple representations (bit strings). Baker and Ayechev (2003) demonstrated that GAs is an effective approach for solving the basic VRP (vehicle routing problem). Although the pure GA that they have developed works reasonably well, it appears to be better to view the GA more as a means of diversifying their exploration of the solution space, alongside neighbourhood search. Lu et al. developed new approaches for

simulation based model for one plant multi-site ready mixed concrete production system, by real-life data in Hong Kong. Zayed and Minkarah (2004) illustrate the concrete batch plant example presented as a case study to demonstrate how simulation can be of benefit. Simulation sensitivity analysis is used to generate useful decision-making tools for plant operation. Feng et al. (2004) describes the characteristics of the RMC industry and then analyses the factors that impact the RMC delivery process. Finally, a model that incorporates Genetic Algorithms (GA) and simulation technique is built to find the optimal dispatching schedule which minimizes the total waiting duration of RMC trucks at construction sites and satisfies the needs of RMC deliveries requested by different construction sites.

Cao et al. (2004) developed a replacement approach for concrete plant manufacturing and delivery process optimization by combining a ready mixed concrete (RMC) production simulation tool (called HKCONSIM) with a genetic algorithm (GA) based optimization method. Tang et al. (2005) developed a simulation computer program named RMCSIM to simulate the operations of a ready-mixed concrete plant serving multiple construction sites using multiple truck mixers. Surico et al. (2005) introduced a new combination of Genetic Algorithm (GA) and Ant Colony Optimization (ACO) algorithms for the optimization of a concrete delivery problems. Feng and Wu (2006) analyses RMC delivering process and then developed a systematic model based on several supply chain management (SCM) concepts. In addition, the fast-messy genetic algorithms (fmGA) and also the CYCLONE simulation technique is integrated together to seek out the best feasible and optimal dispatching schedule which minimizes the ideal waiting duration of RMC truck-mixers at construction project sites without delaying the casting operation. Naso et al. (2007) focused on the ready-mixed concrete delivery problem in addition to find complexity, strict time-constraints of the supply schedule. After developing a detailed model, they proposed a novel based meta-heuristic approach on a hybrid genetic algorithm combined with constructive heuristics. The proposed approach was illustrated with the help of detailed case study derived from industrial data. Reviewing the available literature, it was observed that there is a need to develop a dispatching sequence model for effective delivery of RMC from commercial batching plants. The present study aims at developing a delivery sequence model by application of genetic algorithm for delivering RMC from commercial batching plants to respective construction sites.

## **2. Methodology**

Real time data has been collected from a commercial batching plant located in Ahmedabad district of Gujarat state in India. The real time data comprises of number of transit mixers owned by the plant, dispatching routes from batching plant to respective construction sites, number of deliveries required on each site, quantity ordered on each site, mixing duration, traveling time from plant to site & site to plant, pouring time, buffer duration. The capacity of the batching plant under study is 30 cum / hr and the plant own 08 numbers of transit-mixers out of which 06 are operational. Primarily the data was collected on a daily basis. The analysis was carried out on a one-day requirement of 3 different sites with the constraints of limited number of transit mixers. The required numbers of deliveries are decided on a basis of required quantities of concrete for respective construction sites. The routes are decided by considering minimum

distances; less traffic congestion with the help of GPS enabled devices installed on each transit mixer.

The purpose of using GA is to find the most efficient and effective dispatching sequence of RMC trucks. Since the required number of the RMC trucks can also be determined by different dispatching sequences. Therefore, the chromosome structure used in this study is designed so that all permutations can be represented and evaluated.

First, the length of the chromosome is defined as the total number of the RMC trucks that will be dispatched from the RMC plant. For example, if there are three construction sites that respectively require three, four and five trucks to deliver RMC in the close period of time, the total length of the string would be 12 genes, the sum of three, four and five. Secondly, the random key representation for the genes of the string is used in this study to avoid the infeasible and illegal solutions generated within the evolution process. For the present study, as the RMC plant is supplying to 3 construction sites having their specific routes, the required number of deliveries to each route is 12, 3 and 2 respectively, so the total length of the sequence will be (12+3+2) i.e. 17. according to eq. (1) for the 17 solution spaces 17 random numbers are generated and site IDs are assigned.

The total solution space of the dispatching schedules can be determined by the following equations:

$$TS = \text{Sum of Required quantity of concrete on each site} \quad (1)$$

In practice, the distance (km) from the batch plant to the construction site can be found by using the Google Earth. In this study, the average speed of RMC truck traveling from the batch plant to the construction site is 30 km/ hr. Therefore, the traveling time from the batch plant to the construction site  $j$  (in min) can be computed from eq. (2). The average speed of RMC truck returning back from the construction site to the batch plant is 40 km/ hr. Therefore, the returning time from construction site  $j$  to the batch plant (in min) can be computed from eq. (3).

$$\text{Travelling time (Go)} = D \times 2 \quad (2)$$

$$\text{Travelling time (Back)} = D \times 3 \quad (3)$$

$D$  = Distance from the batch plant to the construction site (km).

### 2.1 Fitness Value (Objective Function)

An efficient dispatching schedule should balance the casting and dispatching processes at the construction sites and the batch plant also. However, the number of RMC trucks that the batch plant owns is limited; it is possible that the batch plant cannot dispatch RMC truck because no trucks are back to the batch plant. In that situation, the requirements of continuous casting concrete operation and avoiding hardening of concrete constrain the RMC trucks to arrive at the construction sites within the allowable buffer duration. Different dispatching sequences could result in the construction sites waiting for the arrivals of the RMC trucks or the RMC trucks waiting in queue for casting concrete. Therefore, the fitness value of a dispatching schedule is determined by minimizing the total duration that the RMC trucks wait



at the construction sites, which can be determined by the simulation process. The fitness value or objective function is defined by the following equation, where the minimum of the total waiting time need to be computed:

$$\begin{aligned} \text{Objective function} &= \min (\text{Total Waiting Time}) \\ &= \min (\text{TDG} + \text{WT} + \text{CD} + \text{P}) \end{aligned} \quad (4)$$

Where, TDG = Travel time from plant to site; WT = Waiting time at respective site; CD = Concrete pouring time and P = Penalty function depending upon the number of obstructions from plant to site. Travel time from plant to site would depend upon the traffic conditions in the route and also upon the obstructions in the route like speed breakers and traffic signals. Waiting time at respective sites may be due to the transit-mixer waiting for the RMC to be delivered or the site is waiting for the transit-mixer to reach. Concrete pouring time would depend upon the structure in which the concrete is being poured. Structures like raft slabs would take longer pouring time due to the large quantity of concrete that need to be poured. Structures like beams and columns need larger time for concrete to be poured though the quantity of concrete to be poured is small. Penalty function would depend upon the number of obstructions in the route of travel like the traffic signals, speed breakers and any other kind of obstructions.

The constraint for this optimization problem is that the maximum permissible time starting from the batching of the RMC to placing of RMC at respective site is 120 minutes. Thus the constraint is defined as:

$$\text{Constraint: } \text{TDG} + \text{WT} + \text{CD} + \text{P} \leq 120 \quad (5)$$

## 2.2 Analysis

Compute the ideal departing time of each RMC transit-mixer. The ideal dispatching process of the batch plant is the process that RMC truck leaves the plant as soon as the RMC truck finishes loading concrete. Therefore, the ideal departing time of each RMC truck is determined by the following eq.

$$\begin{aligned} \text{Ideal departure time of the 1st truck} &= \text{Departure time of 1st RMC truck} + \text{concrete} \\ &\text{mixing and loading time} \end{aligned} \quad (6)$$

$$\text{Simulated departure time} = \text{ideal departure time, if } i \leq c \quad (7)$$

$$\begin{aligned} \text{Simulated departure time} &= \min_{\{i\}} (\text{Returning time of 1st transit-mixer} + \text{Concrete mixing} \\ &\text{and loading time}), \text{if } c < i \leq N \end{aligned} \quad (8)$$

$$\begin{aligned} \text{Arrival time of 1st transit-mixer at site } j &= \text{Simulated departure time} + \text{travelling time} \\ (\text{Go}) \end{aligned} \quad (9)$$

$$\text{Start time of casting at site } j = \text{start casting time at site } j \quad (10)$$

$$\begin{aligned} \text{Waiting duration of dispatched transit-mixer} &= \text{start time of casting at site } j - \text{Arrival time} \\ &\text{of transit-mixer at site } j \end{aligned} \quad (11)$$

Leaving time of transit-mixer = Arrival time of transit-mixer at site j + Waiting duration + Pouring time, if waiting time  $\geq 0$  (12)

Leaving time of the truck = arrival time of the truck at site j + pouring time, if waiting time  $< 0$  (13)

Returning time of the 1st truck = leaving time of the 1st truck + travelling time (backward) (14)

Penalty Function = Number of obstructions for the sequence\*60 (15)

Fitness function (Objective function)= Positive waiting duration for the sequence + Penalty function (16)

Details of the three routes for delivery of RMC from the batching plant are presented in figure 1.

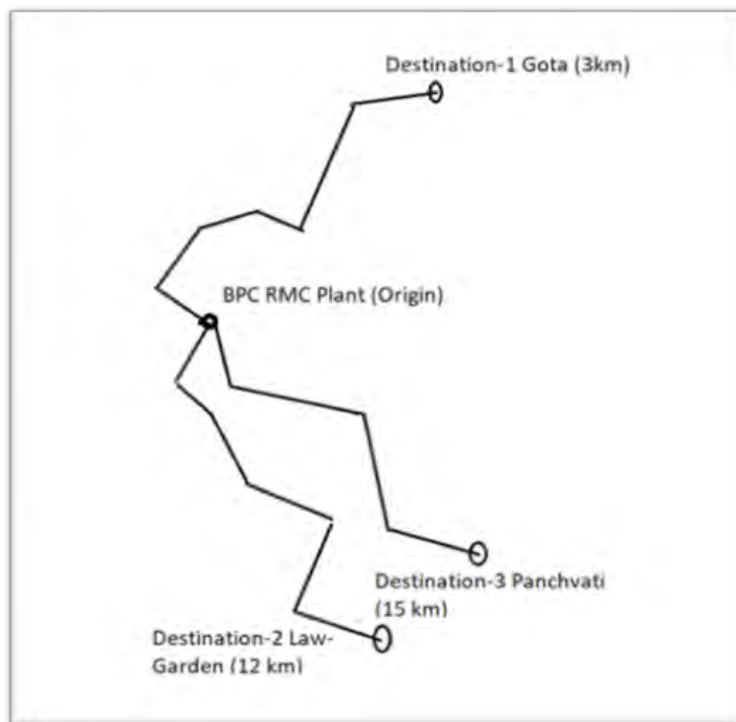


Fig. 1. Routes and destinations for delivery of RMC from the batching plant

Table 1. Real time data of RMC plant of Ahmedabad, India

Route ID	Site ID	Starting time of casting at site	Traveling time (min)		Pouring time
			Forward way	Return way	
1	1	09:30	15	10	15
2	2	09:45	40	30	60
3	3	10:00	50	40	90

Table 2. Real time data of RMC plant of Ahmedabad, India, Continued

Route ID	Site ID	Starting time of casting at site	Buffer Duration (mins)	Required deliveries in each route	Required Quantities In each site
1	1	09:30	15	12	80 cum
2	2	09:45	20	3	15 cum
3	3	10:00	30	2	cum

### 3. Results

There are 3 different routes assigned to 3 different sites and the real time data for each site is given in Table 1. With the help of this data the optimized ultimate dispatching sequence of the RMC transit-mixers were computed. There are 8 RMC transit mixers available with the RMC plant owner out of which 6 are mostly operational. The real time data for the dispatching sequence optimization for RMC are presented in Table 1 and 2.

Considering the above-mentioned equations, a code based on GA was written in MATLAB software. Predetermined crossover probability is 0.5 and mutation rate is 0.1. The population size is 50. The system is run and the output is taken for determining the optimized dispatching scheduling sequence of RMC transit-mixers from batching plant to respective construction site with the help of 100 iterations. The starting time of 1st and 2nd site is 9:30 and 9:45, 3rd site is 10:00. So according to eq. (1) the answer obtained is  $\min(9:30 - 0:30) = 9:00$ , then the ideal departure time is calculated by eq. (4), i.e.  $9:00 + 0:07 = 9:07$  and so on.

Simulated departure time is calculated from eq. (5) and (6). In this study the RMC truck-mixers with the plant owner is limited to six numbers. So 7th dispatching order will be calculated according to the eq. (6). The 1st RMC truck-mixer arrives earlier and departs for the 7th order sequence at  $(9:55 + 0:07) = 10:03$ .

Arrival time of site is calculated by eq. (7) i.e. for site 1 travel time is 15 min so for 1st truck it is  $(9:07 + 0:15) = 9:22$  and so on. Starting time of casting is calculated by eq. (8) i.e. starting time of site 1 is 9:30 so the casting time for 1st truck is 9:30 and so on. Buffer time is the user input time and is different for each site, for 1st site it is 15 min likewise for 2nd it is 20 min and for 3rd it is 30 min. Waiting time is calculated by eq. (9) i.e.  $(9:30 - 9:22) = 8$  min. Leaving time from the site is calculated by eq. (10) and (11). For the 1st truck it is  $(9:30 + 0:15) = 9:45$  and so on. If the waiting time is negative (indicates delay in casting) then use eq. (11) i.e. for 2nd truck  $(9:45 + 0:60+0:09) = 10:54$ . Returning time to plant is calculated by eq. (12) i.e. for 1st truck  $(9:45 + 0:10) = 9:55$

Table 3 and 4 represents the final optimized data for scheduling the dispatching sequence for dispatching order 1 to 8 and 9-17 respectively.

Table 3. Final optimized data for scheduling the dispatching sequence (dispatching order 1-8)

Dispatching order	1	2	3	4	5	6	7	8
Departure time of 1 <sup>st</sup> RMC truck	9.00							

Ideal departure time	9:07	9:14	9:21	9:28	9:35	9:42	9:49	9:56
Sequence	1	2	3	1	1	1	1	2
Simulated departure time	9:07	9:14	9:21	9:28	9:35	9:42	10:02	10:17
Arrival time at site	9:22	9:54	10:11	9:43	9:50	9:57	10:17	10:57
Start time of casting at site	9:30	9:45	10:00	9:45	10:00	10:15	10:30	11:00
Buffer time (min)	15	20	30	15	15	15	15	20
Waiting duration (min)	8	-9	-11	2	10	18	13	3
Leaving time from site	9:45	10:54	11:41	10:00	10:15	10:30	10:45	12:00
Returning time to plant	9:55	11:24	12:21	10:10	10:25	10:40	10:55	12:30

Table 4. Final optimized data for scheduling the dispatching sequence (dispatching order 9-17)

Departure time of 1 <sup>st</sup> RMC truck	9.00								
Dispatching order	9	10	11	12	13	14	15	16	17
Ideal departure time	10:03	10:10	10:17	10:24	10:31	10:38	10:45	10:52	10:59
Sequence	1	1	1	2	3	1	1	1	1
Simulated departure time	10:32	10:47	11:31	12:28	11:02	11:19	11:32	12:02	12:37
Arrival time at site	10:47	11:02	11:46	12:43	11:52	11:34	11:47	12:17	12:52
Start time of casting at site	10:45	11:00	11:30	12:30	12:00	11:45	12:00	12:15	12:30
Buffer time (min)	15	15	15	15	30	15	15	15	15
Waiting duration (min)	-2	-2	-16	-13	8	11	13	-2	-22
Leaving time from site	11:02	11:15	11:45	1:43	1:30	12:00	12:15	12:30	1:07
Returning time to plant	11:12	11:25	11:55	2:13	2:10	12:10	12:25	12:40	1:17

#### 4. Results

Now according to Table 3 and 4 the fitness function can be calculated by adding all positive waiting times i.e  $8+2+10+18+13+3+8+11+13 = 86$  min with considering number of negative waiting times having higher negative value than the allowable buffer time. A penalty function is calculated with the help of eq. (13) i.e there are two obstructions noticed while delivering concrete, out of which one is of about one minute which can be ignored. The remaining one would be considered as an obstruction, so penalty would be  $1*60=60$  mins.

Now the fitness function for the said dispatching sequence “1 2 3 1 1 1 1 2 1 1 1 2 3 1 1 1” would be  $60+86=146$  min according to the eq. (14). As the negative waiting time is more

than the allowable buffer time for that site-1 in the 17th order sequence, but the overall waiting time of the sequence is the least and so it is the ultimate optimized dispatching sequence from the 100 iterations mentioned above.

## 5. Conclusions

The ultimate dispatching sequence “1 2 3 1 1 1 2 1 1 1 2 3 1 1 1” comes up, it has been observed that the waiting time of RMC truck was within assumed allowable buffer duration of respective project sites, but the waiting time of site was about 7 mins due to late arrival of RMC truck. Also the waiting time for the above dispatch sequence after validating the model is  $8+2+10+18+13+3+8+11+13=86$  min. Further, the fitness function after addition of penalty function for one obstruction is  $86 + 60 = 146$  mins. This matches with the results obtained after 100 iterations in MATLAB. Tremendous savings in total waiting time can be achieved with the help of genetic algorithm tool. Required number of iterations completely depends on level of accuracy needed by the end user. It is recommended that the RMC plant authorities should increase the number of RMC transit-mixers from six to eight. This would definitely reduce the waiting duration of the respective sites for arrival of RMC trucks to start their casting operation.

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# Key Success Factors for Better Quality at Delivery in Construction Projects

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## Abstract:

This paper presents the results of research conducted in B&H, aimed to demonstrate the possibility to identify the importance of a standardized project management process to the delivering expected quality. Throughout the interviews (direct participants with different managerial perspectives in the phase of conception, definition and planning and execution/execution), 75 construction projects were assessed across different project phases. Factor analysis yielded three key success factors for the three factors covered ten variables. The first key success factors R1 - resources covered: planning and control; involvement, teamwork; expertise, knowledge...; communication; coordination between project participants; the availability of resources. The second factor R2 - management covered: focus on the customer; top management support/commitment; continuous improvement; supplier's quality management. The third factor R3 - quality police encompassed: quality policy, like part of quality project management process. The factor Q1 - product quality with four variables like product quality of this phase. These results can help participants in construction projects to focus on the key quality factors which were marked as important for the phases in which they participate, and use them as indicators and in that way direct the project towards achieving the final quality of the product.

*Keywords: project management process, quality, factors, product, results*

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## 1. Introduction

Project management will not be adopted, without the support of the top management. Project management for them does not represent almost anything or very little, as a result, there are shortcomings in projects. Research shows that small and medium-sized companies make up 99.8% of all companies in the EU. They generate 56% of GDP and employ 70% of private ownership. The results have shown that in small and micro companies there is no tendency to use known tools and techniques for project management (Turner et al., 2010).

Quality is important for modern organizations because it increases competitiveness and productivity, reduces costs and ensures long-term cooperation with the customers (Dolaček-Alduk et al., 2009). One of the researches does not indicate that risk, safety and quality are direct problems, but they are indirectly created by the organization of time and resources involved in the implementation of the project (Hoonakker, 2006).

15.7 million new project management roles will be added globally across seven project-intensive industries by 2020, and construction is one of those industries (PMI, 2013).

Project management has evolved over the past couple of decades. Traditional project management skills were developed from the requirements of construction industries to plan, control and manage large and complex 'tangible' projects (Morris, 1994; Bourne and Walker, 2004).

According to Ogwueleki (Ogwueleka, 2013), project management can be improved through a process of quality management and so through proper project management the realization of the quality of the project can be improved.

Participants in construction (Investor, Contractor/Subcontractor, Designer, Project Manager, Consultant), as well as the end users of the project will directly benefit from the research on the mutual influence of the quality of the project management process on the quality of the end product, i.e. the constructed structure.

The research methodology for modeling was the following: analysis and synthesis of the literature overview. Eleven key quality factors (project management process) were identified and used in further research. The next step was an analysis of the results obtained from the interviews related to the "quality" of products for each phase of the project, which was also used as input data for the process of modeling. Afterward, all the measuring variables were defined in order to be "recorded" through interviews during real projects. Followed by factor analysis in order to group the factors of quality of the project management process and product, that are used as an input during the modeling process, a hypothetical - zero and final model was created after that. Moreover, we have identified the main factor throughout the three phases which put a new focus to the importance of the linkage between PM and Quality in construction. The research was conducted in Bosnia and Herzegovina (B&H) on construction projects, which presents the basis for further research that goes in the direction of forming a model that will be easily applied in practice, and will show the impact of project management on the quality.

The main aim of the research was to demonstrate how standardized project management (PM) practices positively influences the end quality at delivery. This would lead to a better understanding of the importance of PM in the construction industry, but also would provide a set of key PM factors construction companies could use to predict the quality at delivery and employ as leavers for quality improvement.

## **2. Literature overview**

### *2.1. Project, project phase, project management*

The project is specified time commitment focused towards the production of a specific product, service, or result by the Project Management Institute (PMI). It is clearly visible from this definition that a project is a temporary activity in nature, which means that it has its beginning and its end, and is existent with the purpose of creating a specific product (PMI, 2013).

The International Project Management Association (IPMA) defines a project as a unique, temporary, multi-disciplinary and organized endeavor to realize agreed deliverables within predefined requirements and constraints (IPMA, 2015).



The project phases are: start/concept, planning/definition, performance/execution, monitoring and control, project closure by IPMA (IPMA, 2013).

According to PRINC 2 the division of the project into phase is the following: initiation, start, direction, control, management of delivery and finalization (PRINCE 2, 2002).

Chin (Chin, 2012) shares the project on phases: initiation/concept, definition, planning and closure.

In this research, the focus is placed on the following phases: start/concept, planning/definition, performance/execution. The project closure phase is not analyzed, because it is not highly influenced by quality factors. This paper showed the resultants for the selected project phases. One of the goals is to show a link between quality factors of the project management process and the product on the project phase.

At the beginning of project management development, in the early 60' of last century, companies and other organizations noticed the significant advantages of work and task organization, as well as the critical for communication and work integration through various sectors of the profession. ([www.projektura.org](http://www.projektura.org)) In order to provide benefits required by the owner, project management is a way of managing and controlling the expenditure of resources granted to a temporary organization (Turner, 2006).

IPMA (IPMA, 2015) defines project management as planning, organization, monitoring and control of all the project aspects, including the motivation of everyone involved to accomplish the project goal through a secure path, within the prearranged time, expense and performance criteria's. Project management is performed through processes and includes the integration of the various phases of the project lifecycle.

## *2.2. Quality factors*

We have found many studies that we're dealing with factor influence of Quality Management (quality factors, e.g. safety management) in the literature, but we could not have found any study about explicit quality factors of the project management process.

In the one studies, we found the next quality factors:: program monitoring, employee involvement, expertise and training systems involved in the project, incomplete or inaccurate cost estimates, focus on the customer / client, organizational skills, communication, continuous improvement, interpretation of the expectations of the buyer / customer, quality policy, changes during the project realization, availability of resources, project environment, implementation of relationship between time and cost, uniqueness of the project, organizational skills (Ogwueleka, 2013).

Eleven quality factors were identified in previous research like key quality factors of project management process (planning and control; involvement; teamwork, knowledge; expertise; customer satisfaction; top management commitment; communication; continuous improvement; coordination between project participants; quality policy; availability of resources and supplier quality management) (Ljevo et al., 2017).

The quality of a product or service is determined by the relation between execution by the manufacturer, and the wishes or needs of the users. The quality of the products of each phase of the project, or the project as a whole, it refers to the delivered object.

The research by Flyvbjerg (Flyvbjerg, 2012) shows that as many as 80-90 % of customers/users are primarily concerned with the quality characteristics of the product. It is not surprising that quality is like the most important phenomenon of our age, and the last century is considered to be a century of quality.

For example the planning phase, the following factors were ranked best by the participants in the project: complete technical documentation (main project, a study of occupational safety and other legally required documentation); obtained urban approval and building permits; planned budget; customer satisfaction at the end of the phase (new processes, methods or technology).

### **3. Research Hypotheses**

The quality of the project is defined as two dimensions: product quality and process quality (Turner, 2002). Three criteria or objectives for assessing the success of the project are time, cost and quality (iron triangle) identify in the literature on project management. The quality of the project, being the third dimension of the "iron triangle", is much more difficult to define, assess, plan, and control. For the first two objectives there are a number of exact methods for planning and control. This represents the backbone of the research the linked of the process quality on the product quality will be studied in the phase of the project for this paper. Thus in this research, we have found that one of the hypotheses which we want to prove is:

H: The link between quality factors of the project management process and the product differs depending on the project phase.

### **4. Research methodology**

Throughout the interviews (direct participants during the phases), 75 construction projects were studied and assessed in order to define the list of critical success factors that project managers found important for better delivery of quality and identify criteria of quality at delivery. In the literature has been identified quality factors as factors of the process (project management process) and product (deliverables). After analysis and consultation with university professors, quality factors were selected and adapted. The final list of the factors and criteria was then used for collecting data from construction projects. After having defined the key factors of quality management processes, we ran the survey in Bosnia and Herzegovina. The next step included evaluations (scores) of each individual variable, recorded through structured interviews and identification of differences in factor analysis of results obtained through interviews and case studies. A questionnaire consisting of questions about the latent variables and their constituent variables explained in the preceding sections was designed to analyze the influence of “quality of project management processes” on “quality at delivery“. The factor analysis was carried out which had suggested the null model of linkage between the quality of the PM processes and product quality.

While conducting Confirmatory Factor Analysis (CFA), construct validity should be satisfied by using content validity and empirical validity tests. Using factor analysis we grouped factors of the quality of the project management process (variables in new factor) and product quality that could be used as inputs during the modeling process. Once the measurement model is validated, the structural relationships between latent variables are estimated (Hair et al., 2010).

Exploratory factor analysis is a descriptive technique that can detect an overarching structure that explains the relationships between items in a parsimonious way. Confirmatory factor analysis differs from exploratory factor analysis by allowing the investigator to impose a structure or model on the data and test how well that model, and that is the null model for each project phase.

## 5. Data analysis and results

In the first step used factor analysis as a useful tool for investigating variable relationships for complex concepts for data collected from 75 respondents were analyzed using a software package called SPSS 20. This research applied factor analysis to explore the groups of quality management process factors and factors of a quality product. After a factor analysis of the data, the null model suggests the impact of the process quality (project management) on product quality.

The research analyzed 57 (76%) building construction projects and 18 (24%) engineering projects. The value of the analyzed projects is shown in figure 1, most of them 34.7% are between 500.000-2.500.000 €, less the 5000.000 € is 8.00%.

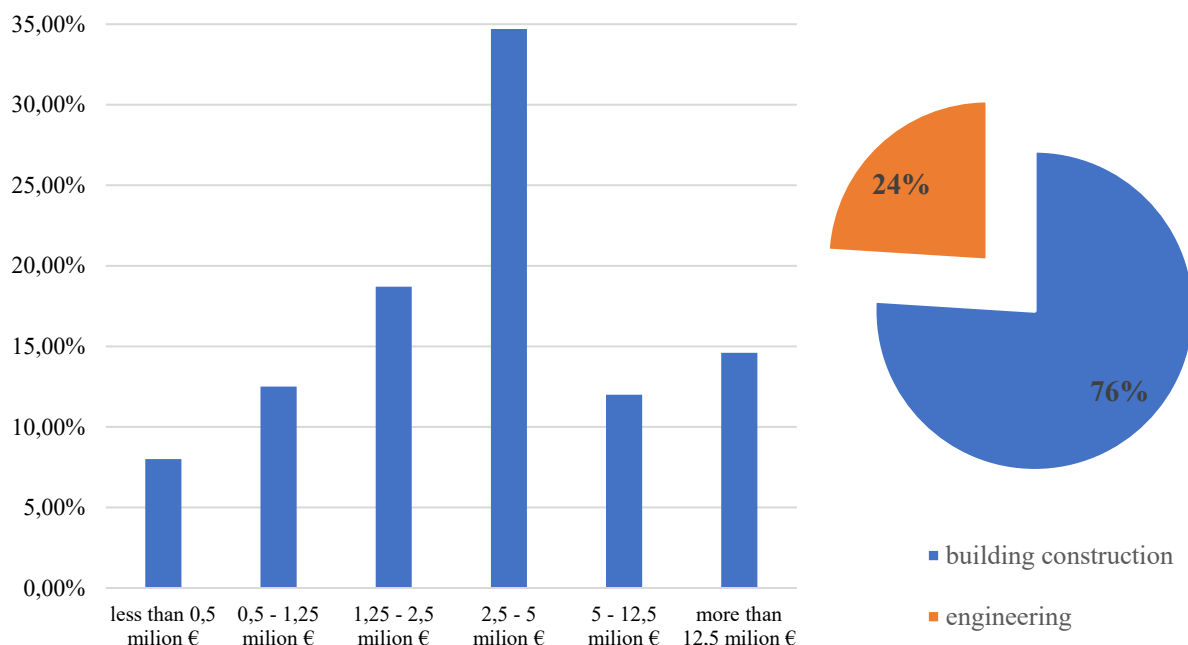


Figure 1. The tipe and value of project

Scale reliability is the internal consistency of a latent variable and is measured most commonly with a coefficient called Cronbach's alpha. The purpose of testing the reliability of a construct is to understand how each observed indicator represents its correspondent latent variable. A higher Cronbach's alpha coefficient indicates a higher reliability of the scale used to measure the latent variable.

Table 1: Cronbach alpha for quality factor

	Cronbach alpha			
	Quality project management process factor			Quality product factor
project phase	R1	R2	R3	Q
concept	0,787	0,803	0,738	0,740
definition and planning	0,803	0,787	0,742	0,706
execution	0,906	0,729	-	0,860

After the factor analysis, the following latent success factors were identified: (in concept phase) factor R1 covered the shared variability of the following variables: planning and control; communication; continuous improvement; coordination between project participants. Factor R2 covered: involvement, teamwork; focus on the customer; top management support/commitment; quality policy, and the factor R3 encompassed: expertise, knowledge ...; the availability of resources; supplier's quality management. For the concept phase, 62.6% respondents consider that the key factor of quality is the customer satisfaction at the end of the phase (compliance of project tasks (scope, concept, structure, etc.) with the business plan), 59.3% state that the key factor is the secured financing and 54.6% sustainable construction plan.

Factor analysis results (in defining and planning phase) are provided below. The first latent value called "planning and resources – R1", includes the following variables: planning and control, involvement and teamwork, and availability of resources. The second latent value called "management – R2", includes the following variables: the focus on the customer, top management support/commitment, quality policy, and supplier's quality management. The third latent value "coordination – R3", includes the following variables: expertise and knowledge, communication, and coordination among project participants. On the other side of the model is one latent variable (new factor - Q), which includes four variables manifesting for this phase: complete technical documentation, acquiring urban and building permits, difference between predicted and planned budgets, as well as sustainable budget of the building, and customer's satisfaction at the end of the phase (the number of new processes, methods, or technologies that are envisaged at this phase), which constitute a new factor called "product quality". (Ljevo et al., 2017).

After the factor analysis the following latent success factors were identified: (in execution phase) the factor "resources – R1" covered the shared variability of the following variables: planning and control; involvement, teamwork; expertise, knowledge ...; communication; coordination between project participants; the availability of resources. Factor "coordination – R2" covered: focus on the customer; top management support/commitment; continuous improvement; supplier's quality management, and the factor "quality policy – R3"

encompassed: quality policy. For the execution phase, 52.7% respondents consider that the key factor of quality is the customer satisfaction at the end of the phase (client got it what he expected according to the business plan), 42.6% technical inspection and obtained usage permit, 29.7% handover without errors and 28.4% defects and the difference between the planned and final construction cost. In first step exploratory factor analysis (figure2).

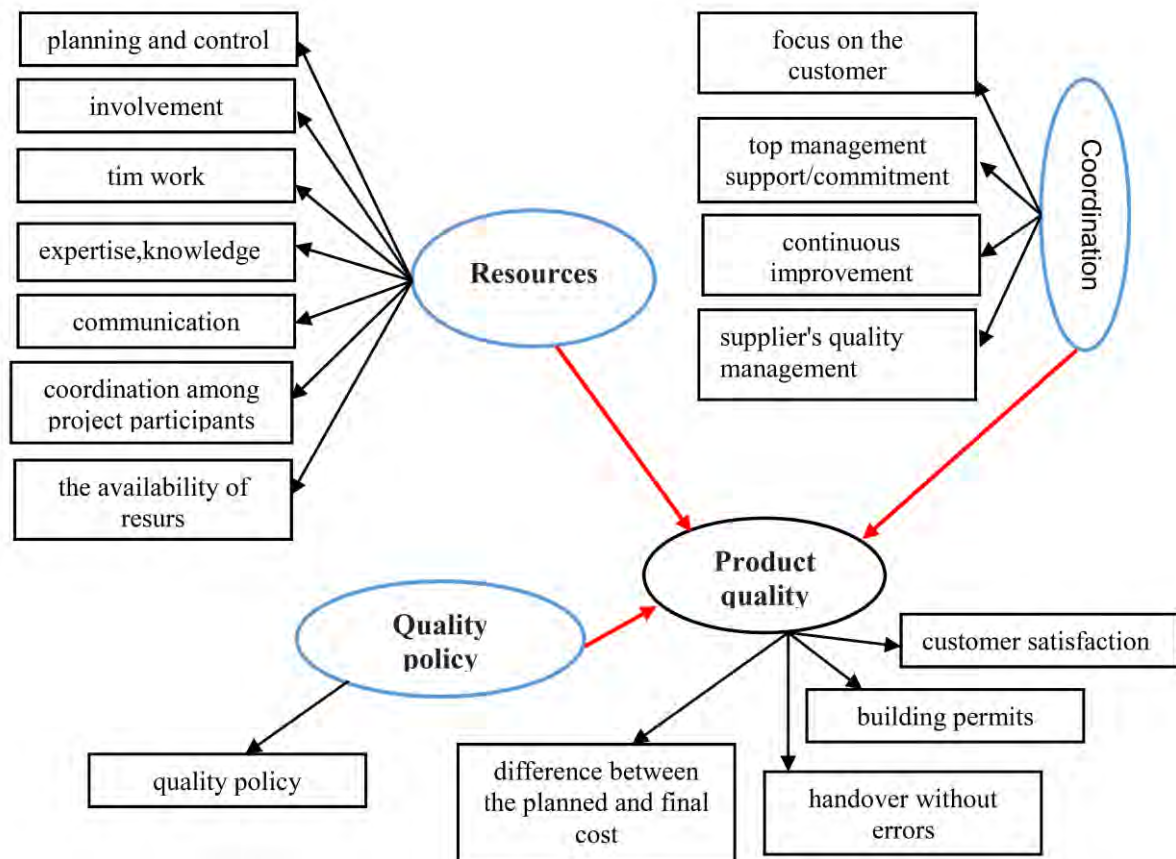


Figure 2: A null model for the execution phase

## 6. Conclusion

Factor analysis resulted in three new factors that included eleven variables (quality project management process), but in the different project phases, a group of variables that make the factors are not the same. Phase defining and planning: three new factors that included ten variables (the variable continual improvement was excluded since the measure of sampling adequacy was less than needed): “R1 - planning and resources – three variables”, “R2 - management – four variables” and “R3 - coordination – three variables” like part of quality project management process and one factor “product quality” with four variables like product quality of phase defining and planning. But in phase execution factor “R1 - resources” included six variables, “R2 - management – four variables” and “R3 - quality police – one variable”.

Therefore, it is necessary (variables) to be controlled, monitored and improved. Variable planning and control like the part of the factor “planning and resources” in defining and planning phase is measured by new methods, techniques, tools and technologies used at this stage. Without good planning, teamwork, phase defining and planning could not have quality project management, and that is also the quality end product phase.

In this research, we have found that the initiative that the link between quality factors of the project management process and the product differs depending on the project phase.

Above mentioned results can help participants in construction projects to focus on the key quality factors which were marked as important for the phases in which they participate or are rated as important for the entire project, and use them as indicators and in that way direct the project towards achieving the final quality of the product.

Projects case studies in this research are limited by their size (budget) because the most analyzed project had a value less than 12.000.000 €. The laws in B&H absolutely do not cover the project management area, so it is left to the companies and direct participants in the projects to decide whether they will use and apply them or not, and that was the problem in this research.

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# Distinction in FIDIC Conditions of Contract for Construction Editions 1999 and 2017

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## Abstract:

FIDIC Conditions of Contract for Construction for building and engineering works designed by the Employer, so-called the Red Book, revised edition was published in 2017. The previous version was published in 1999, 18 years ago. When contracting construction projects co-financed by the European Union, the FIDIC Conditions of Contract are applied. The Red Book is the most commonly used practice in Croatia and to this day the 1999 version is still in use. In FIDIC 2017, the extent of the general conditions as well as the number of clauses increased. For business entities that exercise FIDIC Red Book it is important to distinguish the novelties in 2017 edition, for the implementation of the revised edition is soon expected. By comparing these two editions, within this article, authors will present differences and novelties introduced in the FIDIC Red Book 2017. The purpose of this paper is to show significant difference and to compare clauses of the General Conditions of the FIDIC Red Book edition 1999 and 2017.

**Keywords:** FIDIC; Red Book 1999; Red Book 2017; implementation; differences; contract

## 1. Introduction

FIDIC Red Book is used for contracts in which building and engineering works are designed by the Employer or another company designated by the Employer. FIDIC Red Book edition 1999 has been the most commonly used international form of building contracts in Croatia.



Figure 13. Covers of the FIDIC Red Book editions 1987, 1999 and 2017 (Source: [www.fidic.org](http://www.fidic.org))

In 2017, FIDIC launched new editions of the FIDIC Red, Yellow and Silver Books at its annual International Conference in London. Key features of the 2017 forms include:

- new (and more) definitions and a broader interpretation clause;

- more detailed contractual provisions and guidance;
- an extended role for the Engineer;
- variations and claims to be dealt with as they arise;
- more equivalence of obligations of the parties;
- the old clause 20 being split into two clauses; and
- the introduction of ‘dispute avoidance’.

FIDIC Red Book is divided into three main section: General Conditions; Guidance for the preparation of particular conditions with annex Forms of securities; and, the third section are Forms of letter of tender, letter of acceptance, contract agreement and Dispute adjudication avoidance agreement. This article focuses on changes within General Conditions and mainly on those in General Provisions, the Employer, the Engineer, the Contractor, Claims and the DAAB.

## 2. Difference in General Conditions of the FIDIC Red Book

The difference within editions is noticeable at first sight – the 2017 edition is heavier, with the increased number of pages, chapters, clauses and definitions.

Table 1. Visual distinction between the Red Book

	1987	1999	2017
Weight	400 g	600 g	1000 g
Pages	80	104	194
GC pages	37	68	124
clauses	-	20	21
words	23.600	30.400	50.000+
definitions	30	58	88

However, the changes that are important are one in the instructions, requirements and rules for the Employer, the Engineer, the Contractor and the DAAB. FIDIC 2017 focuses on avoiding disputes. The Engineer is instructed to act neutrally while trying to reach agreement between Parties or make a determination of the matter or Claim. When making a claim, the Employer and the Contractor now have the equal procedures. The DAB (Dispute Adjudication Board) is renamed into the DAAB (Dispute Avoidance/Adjudication Board) and is given the possibility to advise the Parties through Sub-Clause 21.3 Avoidance of Dispute. The DAAB has to be appointed within 28 days (Sub-Clause 21.1 Constitution of the DAAB) so it became so-called standing DAAB – the one who is present at meetings and visits the Site regularly, throughout the entire life of the project.

For the first time FIDIC 2017 gave Advisory Notes to Users of FIDIC Contract, advising the users how to include Building Information Modelling Systems. Unfortunately, this novelty will not be addressed within this article.

It is also important to mention that FIDIC 2017 introduced the possibility of correspondence via e-mail. Notices or other communication sent via e-mail are deemed to have been received the next day after transmission, if there is no non-delivery notification.



### *2.1. General Provisions (Clause 1)*

The first distinction within General Conditions of the 2017 Red Book are the Definitions. They are no longer subdivided into sections but sorted alphabetically. Apart from increased number of definitions and a large number of new definitions, many of them are modified. There are 88 Definitions in the 2017 Red Book unlike the 58 of them in 1999 edition, but only 18 of them remained unmodified.

In the authors' opinion some of the most important new definitions are the definitions of Claims, DAAB, DAAB Agreement, Dispute, Joint Venture, No-objection, Notice and Exceptional Events.

Other changes within General Provisions are recognition of joint venture (JV), time limit of 35 days to sign a Contract Agreement (time limit was 28 days), rights of the Employer to use Contractor's Documents under Sub-Clauses 15.2, 15.5, 16.2 or 18.5, new Sub-Clauses 1.12 Confidentiality, 1.15 Limitation of Liability and 1.16 Contract Termination.

### *2.2. The Employer (Clause 2)*

The Red Book 2017 brings changes to the role of the Employer. The most significant changes are contained in the Financial Arrangements. (Sub-Clause 2.4) The Employer's arrangements for financing the Employer's obligation under the Contract shall be detailed in the Contract Data. Compared to the previous issue where the Employer shall submit, within 28 days after receiving any request from the Contractor, evidence that financial arrangements have been made and are being maintained which will enable the Employer to pay the Contract Price. However, there are still some situations in FIDIC 2017 whereby the Employer is obliged to deliver evidence for financial arrangements. One of them defines an Employer's obligation to provide the Contractor Notice, if the Employer is requested to provide evidence about financial arrangements in case when the accumulated total of Variations exceeds thirty percent (30%) of the Accepted Contract Amount.

In FIDIC 2017 (Sub-Clause 2.3) the Contractor has possibility of request removal of any person of the Employer's Personnel or the Employer's other contractors who is found, based on reasonable evidence, to have engaged in corrupt, fraudulent, collusive or coercive practice.

Further, two chapters have been added to Sub-Clause 2.5 [Site Data and Items of Reference] which define Employer's obligation to provide information to the Contractor before the Base Date. Also, a new Sub-Clause 2.6 [Employer-Supplied Materials and Employer's Equipment] has been added defining Employer's obligation to include in a specification of materials and equipment provided by the Employer.

Except for a part directly related to the Employer, differences concerning the Employer are contained in other clauses. Below are some of the important clauses with an overview of significant differences.

### *2.3. Employer's Taking Over (Clause 10)*

According to FIDIC 1999 it was deemed that The Works were taken over by the Employer when they have been completed in accordance with the Contract and when Taking-Over Certificate has been issued. Except those situations, FIDIC 2017 defines that the Works would not be considered complete, and would not be taken-over unless the Employer has given (or is deemed to have given) a Notice of No-objection to the as-built records and maintenance manuals, or when the Contractor has carried out the training in accordance with the specifications.

### *2.4. Termination by Employer (Clause 15)*

Sub-Clause 15.1 [Notice to Correct] define Engineer's obligation to require the Contractor to correct the failure, with the difference in Red Book 2017 defining contents of the Notice and the Contractor's obligation to respond immediately by giving a Notice to the Engineer with describing the measures which will have been taken to remedy the failure, and stating the date on which such measures will be commenced.

Sub-Clause 15.2 [Termination for Contractor's Default] contains very important changes. Additional termination rights have been added. The Employer has right to terminate the Contract if the Contractor fails to comply with a notice to correct, a binding agreement, final and binding determination, or a decision of the DAAB. Except for the mentioned reasons, the Employer would be entitled to terminate the Contract if Delay Damages exceed the maximum amount stated in Contract Data.

There is no longer any restriction for termination the Contract for the Employer's Convenience (Sub-Clause 15.5) in order to execute the Works by other contractor. After termination for Employer's Convenience (Sub-Clause 15.6) the Contractor shall submit detailed supporting particular of the value of work done and the amount of any loss of profit or other losses.

### *2.5. Care of the Works and Indemnities (Clause 17)*

The Clause Risk and Responsibility in FIDIC 1999 was renamed in FIDIC 2017 into the Care of the Works and Indemnities. There is now no clause Employer's Risk. The clauses are arranged under the new structure. The new structure of clauses separates indemnities by the Contractor (Sub-Clause 17.4), indemnities by the Employer (Sub-Clause 17.5), and Shared Indemnities (Sub-Clause 17.6).

The Employer's indemnities in favor of the Contractor have now been expanded to include loss of or damage to property, which is attributable to any negligence, willful act or breach of contract by the Employer, Employer's Personnel, or any of their respective agents. The Employer is now required to indemnify the Contractor in respect of all claims, damages, losses and expenses, also in respect of damage or loss of property if damage arises from an event for which the Employer is liable. Both parties' liability under the indemnity provisions shall be reduced proportionately to the extent an event, for which the other party is responsible or has contributed to the said damage, loss or injury.

## *2.6. The Engineer (Clause 3)*

The Engineer's role is expanded and enhanced in Red Book 2017 in regards to 1999. The Engineer could be a legal entity or a neutral person. If the Engineer is legal entity, he shall give a Notice to the Parties of the natural person appointed and authorized to act on its behalf. (Sub-Clause 3.1). Such person is named Engineer's Representative (Sub-Clause 3.3)

Engineer shall act as a skilled professional and be deemed to act for the Employer, as before, but with difference in decision making. When making decisions, the Engineer shall act neutrally between the Parties and shall not be deemed to act for the Employer. The Engineer shall make a fair decision of the matter or Claim, in accordance with the Contract, taking due regard of all of circumstances. (Sub-Clause 3.7)

The Engineer may carry out the authorities attributed to the Engineer as specified in the Contract. If the Engineer is required to obtain the consent of the Employer before exercising a specified authority, the requirements shall be stated in the Particular Conditions. The Engineer do not need any consent of the Employer on the matter of Agreement or Determination. The Employer shall not impose further constraints on the Engineer's authority. (Sub-Clause 3.2)

Novelty in FIDIC 2017 are Meetings (Sub-Clause 3.8). The Engineer or the Contractor's Representative may invite each other to attend a management meeting to discuss arrangements for the future work and/or other matters, connected with execution of the Works.

## *2.7. Agreement or determination (Sub-Clause 3.7)*

Sub-Clause 3.5 in FIDIC 1999 instructed Engineer how to act when it is necessary to agree or decide on any matter. The Engineer was supposed to consult with each Party in order to achieve agreement. If agreement was not achieved, the Engineer had to make a fair decision, taking all relevant circumstances into account. There were no time limits set for the Engineer to make decision; he only had to give notice to both Parties with supporting particulars. The Parties had to execute Engineer's decision, unless or until it was revised under Clause 20.

However, FIDIC 2017 in Sub-Clause 3.7 [Agreement or Determination] elaborates Engineer's procedures and specifically instructs Engineer to act neutrally between the Parties and not to act for the Employer. In order to reach an agreement, the Engineer must consult with both Parties, either jointly or separately, and encourage discussion between them. If the Parties reach agreement, within 42 days (Sub-Clause 3.7.3), the Engineer will issue "Notice of the Parties' Agreement" together with a copy of a signed agreement. In case that Parties do not achieve agreement within the time limit or if they advise the Engineer that an agreement cannot be achieved, the Engineer shall give Notice to the Parties and proceed under Sub-Clause 3.7.2 [Engineers Determination]. Within the time limit of 42 days, the Engineer shall issue a "Notice of the Engineer's Determination", taking in consideration all supporting particulars. If the Engineer does not issue Notice of agreement or determination within the time limit, the Parties will consider that the Engineer rejected the Claim; or in case of a matter to be agreed upon, either Party may refer the matter to the DAAB as a dispute, without the Notice of Dissatisfaction with Engineer's determination. The Notices are binding on both Parties, unless and until they are corrected under this Sub-Clause (3.7.4) or revised under Clause 21. If the Parties find

typographical, clerical or an error of arithmetical nature within the time limit of 14 days, either Party can issue a Notice to the Engineer (under Sub-Clause 3.7.4). Within 7 days, the Engineer has to correct agreement or decision and notify the Parties. If the Engineer disagrees about the error, he/she has to notify the Parties immediately.

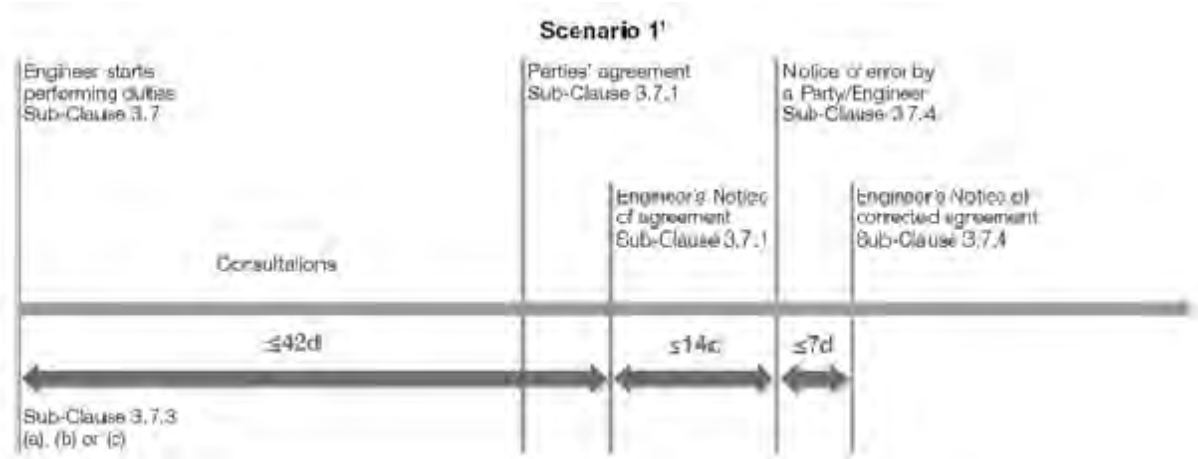


Figure 2. Typical Sequence of Events in Agreement or Determination under Sub-Clause 3.7 – Scenario 1 (Source: FIDIC 2017)

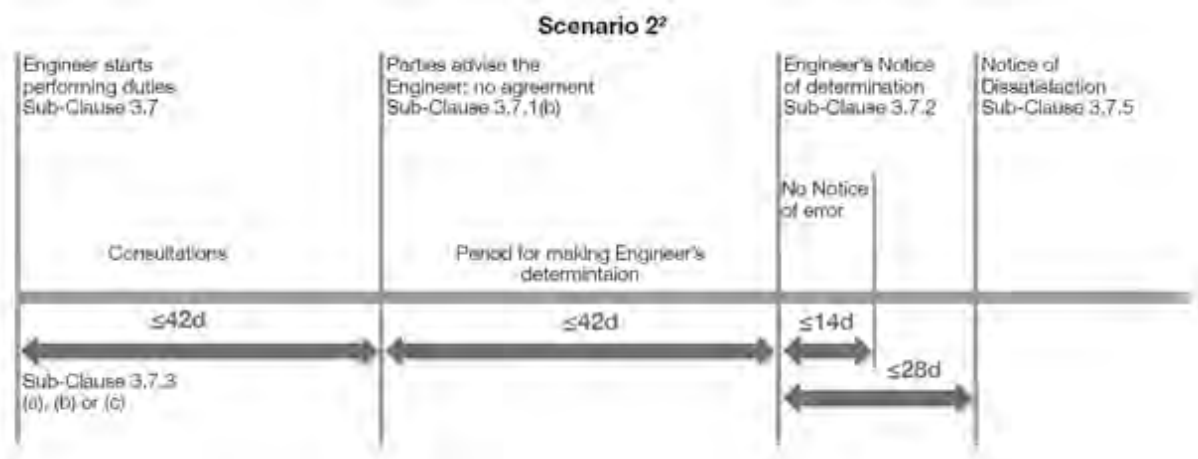
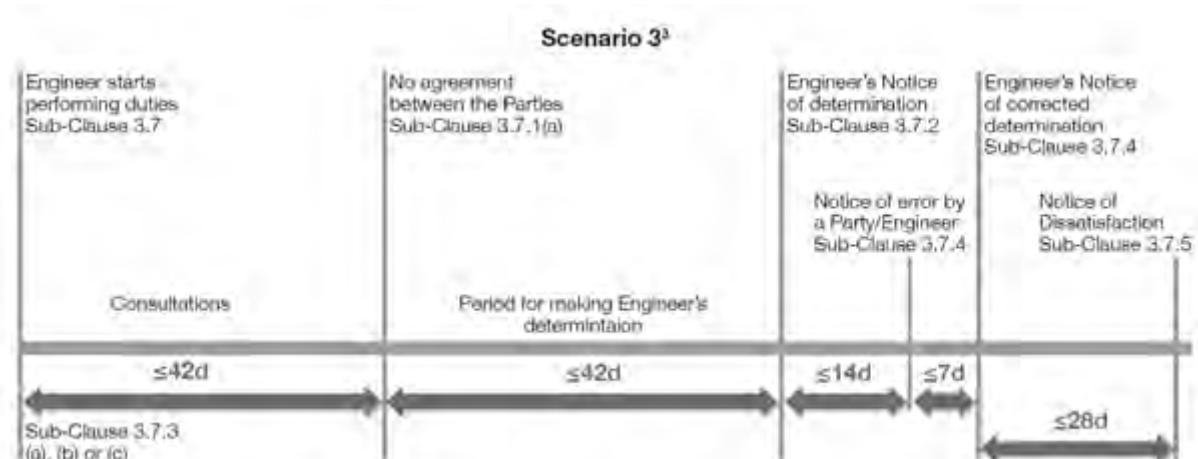


Figure 3. Typical Sequence of Events in Agreement or Determination under Sub-Clause 3.7 – Scenario 2 (Source: FIDIC 2017)



**Figure 4. Typical Sequence of Events in Agreement or Determination under Sub-Clause 3.7 – Scenario 3 (Source: FIDIC 2017)**

If either Party is dissatisfied with the Engineers decision, he/she can issue a Notice of Dissatisfaction (NOD) with Engineer's decision within the time limit of 28 days and under the Sub-Clause 3.7.5. After issuing the NOD, the Party may proceed under Sub-Clause 21.4 – Obtaining DAAB's decision. The Party can also be dissatisfied with part(s) of the Engineer's decision, which must be clearly identified within the NOD. If no NOD is issued, the decision is considered final, binding and accepted by both Parties.

If a Party fails to comply with the agreement or determination, the other Party can refer the matter directly to the arbitration (Sub-Clause 21.6) without prejudice to any rights the Party may have. In that case, Sub-Clause 21.7 applied, in the same way as if it would be applied to the DAAB's decision.

*2.8. Variations and Adjustments (Clause 13)*

FIDIC 1999 refers to Variations initiated by the Engineer in Sub-Clause 13.1. The Contractor shall execute and be bound by each Variation, except in the case when cannot readily obtain the Goods required for the Variation, when he could give a notice to the Engineer stating, with supporting particulars. FIDIC 2017 defines few more cases when the Contractor could give such a Notice to the Engineer. When the varied work was Unforeseeable regarding the scope and nature of the Works described in the Specifications, or when it could affect the Contractor's ability to comply with Sub-Clause 4.8 [Health and Safety Obligations] and/or Sub-Clause 4.18 [Protection and Environment] the Contractor could promptly give a Notice to the Engineer with supporting particulars. Significant difference in Value Engineering (Sub-Clause 13.2), including consideration by the Engineer of the sharing (if any) of benefit, cost and/or delay between the Parties which should be defined in the Particular Conditions. In FIDIC 1999, this fee should be a half (50%) of the difference between amount of such reduction in contract value, resulting from the change, excluding adjustments, and amount the reduction of any reduction (if any) in the value to the Employer of the varied works.

Variation Procedure (Sub-Clause 13.3) under FIDIC 2017 is more detailed and it is split into two parts. First part is a Variation by Instruction, whereby the Engineer may instruct a Variation by giving a Notice to the Contractor, describing the required change and stating any requirements for the modification of Costs. The Contractor shall proceed with execution of the Variation and, within 28 days of receiving Engineer's instruction, submit particular detail to the Engineer. The second part is a Variation by Request for Proposal Procedure. The Engineer may request a proposal, before instructing a Variation, by giving a Notice to the Contractor. The Contractor shall respond as soon as possible by submitting a proposal or giving reasons why cannot comply.

*2.9. The Contractor (Clause 4)*

A separate clause in FIDIC 2017 is Contractor's Documents. The Contractor shall prepare all Contractor's Documents (Sub-Clause 4.4) and Employer's Personnel shall have right to inspect the preparation of those documents. If the Specification or the Conditions request

submitting a Contractor's Document to the Engineer for Review, it shall be submitted accordingly, with a Notice from the Contractor, stating that the Contractor's Document is ready for Review and that it complies with the Contract. The Engineer has (or is deemed to have) issued a Notice of No-objection in relation to the Contractor's Documents or give a Notice that the Contractor's Documents fails.

The Contractor's obligations to provide As-Built Records and Operation and Maintenance Manuals have been expanded and are now set out separately (Sub-Clause 4.4).

The clause on quality assurance from FIDIC 1999 has been renamed and extended. New one is called Quality management and Compliance Verification Systems (Sub-Clause 4.9) and is much more extensive. The Contractor is required to prepare and implement a quality management system to demonstrate compliance with requirements of the Contract, and a compliance verification system to demonstrate that the design, Materials, Employer-Supplied Materials, Plant, work and workmanship comply in all respects with the Contract.

#### *2.10. Suspension and Termination by Contractor (Clause 16)*

Additional suspension and termination rights have been added. The Contractor has right to suspension and terminate if the Employer fails to comply with a binding agreement, or final and binding determination or a decision of DAAB, and such failure constitutes a material breach of the Employer's obligation under the Contract. One more additional reason for terminate is if the Contractor does not receive a Notice of the Commencement Date within 84 days after receiving the Letter of Acceptance.

#### *2.11. Insurance (Clause 19)*

In accordance with FIDIC 2017 the Contractor shall effect and maintain all insurances for which the Contractor is responsible with insurers and in terms, both of which shall be subject to consent by the Employer. That is novelty in comparison with FIDIC 1999, which simplified 'the insuring Party'. Insuring Party means, for each type of insurance, the Party responsible for effecting and maintaining the insurance.

FIDIC 2017 describes in detail the insurance provided by the Contractor (Sub-Clause 19.2) with addition of liability for breach of professional duty (Sub-Clause 19.2.3), which is also novelty in comparison to the FIDIC 1999 release.

#### *2.12. Commencement, Delays and Suspension (Clause 8)*

Within 42 days of receiving the Letter of Acceptance, according to both FIDIC 1999 and 2017, the Contractor will commence with the works. The difference in editions is, that FIDIC 2017 gives the Engineer a time limit of not less than 14 days before the Commencement Date, to give a notice to the Contractor, while the time limit according to FIDIC 1999 was 7 days.

Sub-clause 8.3 defines Programme for the execution of the works. Unlike FIDIC 1999, FIDIC 2017 requires the preparation of the Programme using software stated in the Specification or acceptable to the Engineer, and specifies the content of initial or revised programme. FIDIC 2017 added the following content to each programme: the Commencement

Date, the Time for Completion, the dates the Contractor requires the right of access to and possession of the Site, the review periods, the sequence and timing of the remedial work (for a revised programme), all activities logically linked with the earliest and latest start and finish dates, the float and the critical path(s); recognized days of rest or holiday periods, key delivery dates of Plant and Materials, and for revised programme and each activity actual progress, delay (if any) and effect of such delay on other activities. For supporting reports added content is: identification of changes in case of revised programme and the Contractor proposal to overcome the effects of delay. FIDIC 1999 gave the Engineer 21 day to issue a notice after receiving the Contractors programme, either initial or revised. FIDIC 2017, in case of revised program, gives him/her 14 days to issue such notice. If Notice is not issued, the Engineer is deemed to have given a Notice of No-objection and accepted the initial or revised programme. In case when, the Engineer gives a Notice to the Contractor that it is, for certain reason, necessary to issue a revised programme, the Contractor now has 14 days to comply.

It is important to mention, regarding the Programme, that the content of the Programme or supporting reports do not relieve the Contractor of his obligation to issue a Notice under the Contract.

FIDIC 2017 also includes a new sub-clause regarding Advance warning (Sub-Clause 8.4). Each Party, including the Engineer, shall advise each-other in case of future events or circumstances which can: affect the work, affect the performance of the completed work, increase the Contract Price and/or delay the execution of the Works. In order to avoid or minimize the effects of such events or circumstances the Engineer can request the Contractor to submit a proposal under the Sub-Clause 13.3.2 Variation by Request for Proposal.

The Contractor is entitled to EOT, through Sub-Clause 20.2 [Claim for Payment and/or EOT], if the measured quantity of any item of work is greater by more than 10% and if such increase causes a delay to completion. The Engineer shall review such request and in case that other quantities of work were measured less, he/she can decide not to extend time but to even out the Programme. Either way, both FIDIC 1999 and 2017, allow the Engineer to increase but not to decrease the total EOT.

Other novelties within Clause 8 are in:

- Sub-Clause 8.7 [Rate of Progress]: in order to reduce delay (listed under Sub-Clause 8.5.) the Engineer shall apply Sub-Clause 13.3.1 [Variation by Instruction];
- Sub-Clause 8.8 [Delay Damages]: in case of fraud, gross negligence, deliberate default or reckless misconduct this sub-clause does not limit the Contractors liability;
- Sub-Clause 8.11 [Payment for Plant and Materials after Employer's Suspension]: two more reasons were added to payment of the value of Plant and Materials if the work or delivery is suspended for more than 28 days. The Contractor is entitled to payment if the Plant and/or Material were scheduled and ready for delivery during suspension and if the Contractor provides the Evidence that the Plant and/or Materials comply with the Contract;

- Sub-Clause 8.12 [Prolonged Suspension]: the Contractor may agree to further suspension (if the Engineer did not issue Notice under Sub-Clause 8.13 within 28 days) in which case the Parties may agree to EOT and/or Cost plus Profit and payment for suspended Plant or Material.

### 2.13. *Employer's and Contractor's Claims (Clause 20)*

FIDIC 1999 defined claims as Employer's Claims within Sub-Clause 2.5 and Contractor's Claims within Sub-Clause 20.1. FIDIC 2017 regulates Claims, either the Employer's or the Contractor's in one single Clause 20.

Sub-Clause 20.1 defines the reasons why each Party can file a claim, while Sub-Clause 20.2 defines the procedure in case of a Claim under Sub-Clause 20.1 (a) and (b).

Sub-Clause 20.1 defines that a claim can arise:

(a) if the Employer considers that the Employer is entitled to any additional payment from the Contractor (or reduction in the Contract Price) and/or to an extension of the DNP;

(b) if the Contractor considers that the Contractor is entitled to any additional payment from the Employer and/or to EOT; or

(c) if either Party considers that it is entitled to another entitlement or relief against the other Party. Such other entitlement or relief may be of any kind whatsoever (including in connection with any certificate, determination, instruction, Notice, opinion or valuation of the Engineer) except to the extent that it involves any entitlement referred to in sub-paragraphs (a) and/or (b) above.

FIDIC 1999 allowed the Employer to issue a notice as soon as practicable after the Employer became aware of such event or circumstance and in case of extension of DNP before the expiry of such period. Unlike in FIDIC 1999, in FIDIC 2017 both claiming Parties have a time limit of 28 days to give a Notice of Claim to the Engineer describing the event or circumstances that led to the claim. If either Party fails to give a Notice of Claim, they will not be entitled to any additional payment, reduction of the Contract Price, EOT or extension of DNP.

The important novelty within FIDIC 2017 is the Engineer's initial response and the time limit for submission of fully detailed Claim. According to the Sub-Clause 20.2.2, if the Engineer considers that the claiming Party has failed to give a Notice on time, the Engineer has 14 days after receiving the Notice of Claim to give a Notice to the claiming Party with reasons for declining the Notice of Claim. If the Engineer fails to issue such a Notice, the Notice of Claim is considered valid. Regardless of the Engineer's response, if the claiming Party disagrees with the Engineer, it can submit fully detailed claim. In that case, fully detailed claim apart from documentation included with Sub-Clause 20.2.4, shall include details of disagreement and/or justification for late submission.

According to the Sub-Clause 20.2.4, the claiming Party should submit the fully detailed Claim to the Engineer, within the period of 84 days or other period proposed by the Party and



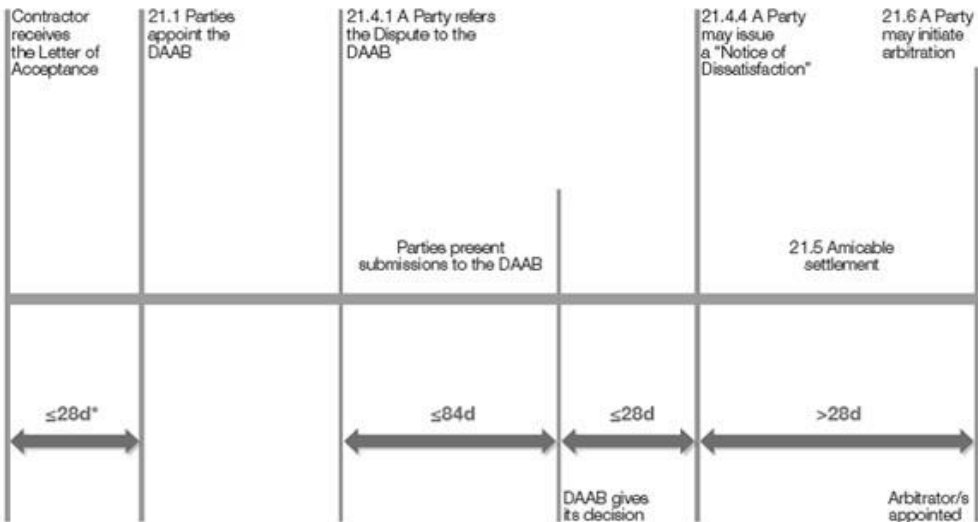
accepted by the Engineer. FIDIC 1999 gave the Contractor only 42 to submit the fully detailed claim. Additionally, Sub-Clause 20.2.4, states that if the Party fails to submit the fully detailed claim, the Engineer has 14 days to issue a Notice that the Party’s claim is no longer valid. If the Engineer does not issue such notice, Notice of Claim is considered valid. However, if the Engineer issues a Notice, but the claiming Party disagrees, the claiming Party can still issue fully detailed claim which shall include details of disagreement and/or justification for late submission.

After the Engineer receives the fully detailed Claim, according to the Sub-Clause 20.2.5, the Engineer shall proceed under Sub-Clause 3.7 [Agreement or Determination]. Even if the Engineer has issued Notice about validity of the Party’s claim, the Claim will be agreed or determined in accordance with this Sub-Clause. Sub-Clause 20.2.5 also suggests the justified circumstances for the late submission, and instructions for the Engineer and the claiming Party, in case that the Engineer requires additional particulars.

FIDIC 2017 also offers instructions in case of a claim with continuing effect (Sub-Clause 20.2.6) and General requirements (Sub-Clause 20.2.7) defining that after receiving the Notice of Claim and until the Claim is agreed or determined, the Engineer shall include in each Payment Certificate such amount for any Claim that has been reasonably substantiated as due to the claiming Party.

2.14. DAAB (Clause 21)

During construction, there are often disagreements between the Parties. Most commonly the Employer and the Engineer on one, and the Contractor on the other side. This is the reason why FIDIC requests the appointment of qualified person(s) to act as a Dispute Adjudication Board (DAB) or as the FIDIC 2017 states Dispute Avoidance/Adjudication Board (DAAB).



\* If not stated otherwise in the Contract Data (Sub-Clause 21.1)

Figure 14. Typical Sequence of Dispute Events Envisaged in Clause 21 (Source: FIDIC 2017)

### *Constitution of the DAAB (Sub-Clause 21.1)*

Just as in Red Book 1999, the Parties jointly appoint the sole or three members of the DAAB. However, the appointment of the DAAB, according to FIDIC 2017, has to be made within the time stated in the Contract Data or no longer than 28 days after the date the Contractor received the Letter of Acceptance. FIDIC 1999 suggested the same, but also allowed the appointment after the dispute has arisen. The terms of remuneration and replacement or termination of the DAAB members did not change in Red Book 2017. What did change is the expiration of the DAAB. According to the Sub-Clause 21.1 the term of the DAAB expires either on the date of discharge (Sub-Clause 14.12) or 28 days after the DAAB has given its decision on all Disputes, whichever is later. Or, in case of the termination of the Contract, the term of the DAAB expires 28 days after the DAAB has given its decision on all Disputes (within 224 days after the termination) or 28 days after the Parties have reached the final agreement, whichever is earlier.

### *Avoidance of Disputes (Sub-Clause 21.3)*

The new and important role of the appointed DAAB, according to Red Book 2017, is avoidance of disputes. In order to avoid disputes, the Parties can jointly request DAAB's assistance to resolve an issue during any meeting or site visit. Also, if the DAAB during meetings or site visits notices an issue, it can invite Parties to make such a request. Such joint request cannot be made while the Engineer is carrying his/her duties under Sub-Clause 3.7. It is important to emphasize that the Parties, but also the DAAB, are not bound by this advice, and if the dispute arise, the DAAB's decision can be different.

### *Obtaining DAAB's decision (Sub-Clause 21.4)*

The same as in FIDIC 1999, either Party can refer the Dispute to the DAAB for its decision. The reference has to be in writing with copies to the other Party and the Engineer, and issued under specific Sub-Clause (21.4). The DAAB has to reach its decision within either 84 days or in a period that it proposed and both Parties had agreed upon. The decision is given in writing to both Parties and the Engineer. The decision is binding on both Parties regardless of issued NOD – "Notice of Dissatisfaction with the DAAB's decision". Novelty regarding DAAB's decision is, if Sub-Clause 3.7 applies to the subject matter of the dispute, the reference to the DAAB has to be made within 42 days of giving or receiving a NOD (Notice of Dissatisfaction with the Engineer's Determination) under Sub-Clause 3.7.5 or it shall be deemed as no longer valid. In case that the Engineer does not comply with the DAAB decision, the Employer is held responsible. FIDIC 2017 also takes in consideration regular payments towards the DAAB. In case that any of DAAB's invoices are left unpaid, it can withhold its decision until outstanding invoices are paid in full. As previously mentioned, within 28 days after receiving the decision, both Parties have the possibility to issue a NOD on DAAB's decision, if not, the decision becomes final and binding on both Parties. Both Parties have to be aware that issuance of NOD does not put DAAB's decision "on hold".

Some of the other novelties within Clause 21 are in:

- Sub-Clause 21.5 [Amicable Settlement]: arbitration may commence on or after 28 day after the NOD was given while the same deadline in FIDIC 1999 was 56 days;
- Sub-Clause 21.6 [Arbitration]: while dealing with costs of the arbitration, the arbitrator(s) may consider the extent to which one Party failed to cooperate to another; and in case that award require payments, this amount shall be immediately due and payable.

### 3. General Conditions and Procedural Rules

In relation to DAAB, FIDIC 2017 offers extended APPENDIX General Conditions of Dispute Avoidance/Adjudication Agreement (GC) and an Annex DAAB Procedural Rules.

GC describes Definitions, General Provisions, Warranties, Independence and Impartiality, Obligations of each Party, Confidentiality, Fees and Expenses, Resignation and Termination, Challenge and possible Dispute under the DAA Agreement. Regarding the GCs we can mention Fees and Expenses that can be agreed to by a monthly or daily fee. The fee is specified in the DAA Agreement and includes availability of the DAAB, all office and overhead expenses, travel expenses, taxes, etc. The Contractor is obligated to pay the DAAB invoices in full and then apply to the Employer for the reimbursement of one-half of the amount. If the Parties cannot agree up on the amount of the fee, the Agreement can still be signed and the amount of the fee will be set by the entity or the official named in the Contract Data.

The Procedural Rules in FIDIC 2017 are well-defined and distinct. They are divided in eleven (11) Procedural Rules: Objectives, Avoidance of Dispute, Meetings and Site Visits, Communication and Documentation, Powers of the DAAB, Disputes, Hearings, The DAAB's Decision, Termination of the DAA Agreement, Objection Procedure and Challenge Procedure; and almost all of them are subdivided in several specific tasks. The objective of the DAAB Procedural Rules, as the Rule 1 in FIDIC 2017 states, are to facilitate the avoidance and to achieve the expeditious, efficient and cost-effective resolution of any Dispute. Important addition to the Procedural Rules in FIDIC 2017 is Rule 2. Rule 2 regulates informal assistance regarding the avoidance of disputes. Informal assistance can be given at any meeting, site visit or by an informal written note to the Parties.

The Procedural Rule 3 regulates meetings and site visits. The same rule existed in FIDIC 1999 but in 2017 version is much more defined. Rule 3 ensures that the DAAB is: informed about the Parties performance of the Contract and the progress of the Works (5.1 d(i) and d(iii) of GCs); informed about any actual or potential issue or disagreement between the Parties; and can give informal Assistance if and when the Parties jointly request such assistance. Rule 3.2 states that after the DAAB's appointment a face-to-face meeting with the Parties shall be held, and a schedule of planned meetings and site visits shall be established in consultation with the Parties. Face-to-face meetings and/or site visits shall be held at a regular interval or at the written request of either Party. The interval of the meetings and/or site visits is regulated by the rule 3.3.: (3.3.a) sufficient to achieve the purpose under Rule 3.1; is no more than 140 days (3.3.b) and is no less than 70 days (3.3.c; except if the Rules 3.5, 3.6 or 7 are applied). Apart from rule 3.3.a, interval of meetings and/or site visits hasn't change regarding FIDIC 1999. In case of critical construction events – suspension of the works or termination of the Contract the

DAAB can visit the site at a written request of either Party. If DAAB accepts that a meeting or site visit is urgent, according to the rule 3.6, it has to hold a meeting by a telephone or a video conference within of 3 days after such request and if the site visit is necessary it has to be held within of 14 days after this meeting. The same as in FIDIC 1999 is that the time and agenda for each meeting is set by DAAB in consultation with the Parties; that the each meeting and/or site visit shall be attended by the Employer, the Contractor and the Engineer; and that the DAAB, at the conclusion of each meeting prepares report on its activities. FIDIC 2017 sets the Contractor in charge to coordinate each meeting and/or site visit, unlike in FIDIC 1999 where the Employer had that obligation.

Rules 4, 5 and 6 in FIDIC 2017 are elaborated, but their main objective did not change in relation to FIDIC 1999. Rule 4 defines communication and documentation. Together with the Sub-Clause 1.4 it defines the language for all communication and regulates the flow of all relevant documentation that the Parties have provided to the DAAB. Rule 5 regulates the powers granted to the DAAB under the Conditions of Contract, the GC and elsewhere within these Rules. And Rule 6 defines how the DAAB shall act in case of a Dispute.

Rules 7 and 8 contain certain novelties in relation to FIDIC 1999. Rule 7 regulates the DAAB's actions and powers during hearings. New addition to this rule is rule 7.3 that states that the DAAB shall not give any Informal Assistance during a hearing except at the Parties request. In that case, as the rule states, the hearing will be adjourned. If the hearing is adjourned longer than 2 days the period within which the DAAB has to make its decision will be prolonged (Sub-Clause 21.4.3) and the hearing will resume after the Informal Assistance has been given. Rule 8 regulates the DAAB's decision. In comparison to FIDIC 1999, the Rule regarding the DAAB decision, whether a sole-member or a three member DAAB, is more detailed and explicit. The novelty about this rule is the deadline of 14 days to express dissatisfaction with the DAAB's decision. If the Parties find typographical, clerical or an error of arithmetical nature, or if the DAAB's decision contains ambiguity, either Party can request clarification and the DAAB has to respond in the next 14 days. The DAAB can decline such request or in order to correct its decision, issue addendum to its original decision. If an addendum is issued, it is considered to be a part of a DAAB's decision and the period in which the Parties can issue the NOD shall be counted from the date they received the addendum (Sub-Clause 21.4.4).

Rules 9, 10 and 11 are a novelty introduced in FIDIC 2017. Rule 9 defines actions that the Parties or the DAAB can undertake in the event of Termination of DAA Agreement. Rule 10 regulates procedure that shall apply if any Party has an objection against a DAAB Member and sets a period of 7 days to issue a Notification about such an objection. The DAAB can respond within next 7 days whereupon the objecting Party may formally challenge a DAAB Member. Rule 11 covers the Challenge Procedure. Such challenge will be decided and administered by the International Chamber of Commerce. Procedure and information on associated charges for such challenge can be found on internet pages: <http://fidic.org> and <http://icwbo.org>.

#### **4. Conclusion**

This article covers only some of the most important changes introduced in FIDIC 2017. The differences are numerous and it is impossible to cover all of them in one article. It is to be expected that the contracting Parties will need time to get acquainted with novelties within the FIDIC Red Book 2017, to accept the new role of the Engineer and the DAAB and to become familiar with the revised contracts. The Engineer and the DAAB have been given new responsibilities in relation to FIDIC 1999 and are expected to behave neutrally between the Parties. The revised Contract form within FIDIC Red Book 2017 is very detailed and complex, while strictly defined responsibilities, tasks and powers gives the Parties assurance of successful execution of the Contract. Although the Contracts are written for Engineers they require legal knowledge and a precise contract administration. The implementation of the revised edition in Croatia is expected as soon as it will be translated, together with the changes that will be included into the Contract.

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# Identification of Success Factors of Dam Engineering Projects in Australia

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## **Abstract:**

There lacks a well-established research on success of projects suggesting working on project success models and improving project performance for specific fields although there exist a huge amount of research outputs and diversity of the project management topics. Dam engineering projects have significant economic, social and environmental impacts. However, their performance over the life-cycle including strategic planning, design, construction and operation has not been systematically studied. Improving dam engineering projects performance is the area that is unknown to researchers and project managers and hence, the purpose of this paper is to fill-in the knowledge gap in this area based on an extensive literature review. It finds a complete list of potential Success Factors as main components for success of dam engineering projects.

*Keywords: critical success factors; dam engineering; project management; project success*

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## **1. Introduction**

Our understanding of project success has changed in recent years. In a recent definition, Kerzner (2014, p. 46) compared the traditional project success definition of completion of project within the triple constraint of time, cost and scope with a new definition with 'value' as an important element in success. He defined project success as "achieving a desired business value within the competing constraints". Walker (2015, p. 311) emphasised on client satisfaction in understanding project success and stated that success of a project is based on "the difference between the client's expectation at the beginning of the project and his satisfaction at its completion". Project success notion is complicated and ambiguous and highly context dependent (Jugdev and Müller 2005). According to Cooke-Davis (2002) from scientific perspective, project success remains an important concern. Such an ambiguity and concern would cause a serious challenge for researchers and there is a rising criticism of research on both general project management and project success in particular (Soderlund 2004). According to Ika (2009, p. 7) "the only thing that is certain in project management is that success is an ambiguous, inclusive, and multidimensional concept whose definition is bound to a specific context". Any study on project success must include decision on determining the success for different stakeholders' perspective, criteria and project phases. In most studies, if success was defined and measured, it is not clear from whose perspective and what time of project life cycle. In order to understand project success, it also needs to be defined in terms of project Success Criteria and Critical Success factors (CSFs) (Turner and Rodney 2009). This research paper focuses on introducing a list for Candidate Critical Success Factors (CCSFs) for dam engineering projects in Australia based on literature review.

Because projects are used for achieving certain objectives, the effort to determine the factors contributing to project success is important for organisations and project managers (Soderlund 2004). Several lists of success factors have been introduced with little agreement on the most important CSFs. The lack of consensus on project success definition provides the opportunity to work on presenting a framework for success of a specific industry as without understanding what constitutes project success, it is not possible to determine what contributes to success. Any preventive or corrective action must take into account the link between the success factors and the criteria as the importance of each success factor might be different in achieving a specific success criterion. Very limited knowledge exists for determining project success factors in dam engineering industry in Australia. Therefore, the problem facing dam engineering projects in Australia is the lack of a comprehensive framework that can be used to increase the chance of achieving objectives of projects in different phases of project life-cycle and to reflect the critical factors influencing the success of this type of projects. Section one of the paper identifies the gap in knowledge of project success in dam engineering industry then the list of potential success factors and their descriptions for the research will be presented in section 3. Research hypotheses and methodology for the PhD research will be presented in section 4 and summary of the paper is presented in conclusion section.

## **2. Research hypotheses and methodology**

In order to address the research problem and answer research question and also to fulfil the hypothesis is set out for testing based on extensive literature review including critical success factors theories. The hypothesis is about identification of applicability of CCSFs in each phase over life-cycle of dam engineering projects.

For the purpose of this research following hypothesis is introduced for testing:

“There are specific CSFs for each phase over life-cycle of dam engineering projects in Australia.”

The purpose is to explore success components of dam engineering projects and identify CSFs from list of CCSFs for each phase of dam engineering projects in Australia. The research will include literature review and establishment of the theoretical framework; data collection and hypotheses testing. The adopted research techniques include Delphi technique in a quantitative way to collect the data. Major statistical analyses will also be conducted to analyse the collected data.

## **3. Dam engineering projects**

Studies and research on the area of project success are very limited in dam engineering industry. In one of the studies Singler (2014) determined CSFs for dam removal projects and suggested following success factors: competent project managers, effective regulations and regulators, effectiveness of dam safety measures, suitable funding. As Hoover dam project had a large impact in modern project management, Kwak et al. (2014) studied the project and introduced that project success during construction was the result of competent project manager, well-defined project mission, creating a design review team, close cooperation between government and project parties and appropriate supply of necessary material. When it

comes to Australian dams engineering industry, the conducted research is even more limited. One of the studies focusing on partnering for Dondeloup dam in Western Australia was by Hellard (1995) who worked on CSFs. The research was limited to project partnering and the dam was among different structures that he studied, so the study was not based on the structure type, but the focus was on success of partnering of civil engineering projects. Review of the literature shows lack of research in the area of success of dam engineering project. Identification of the gap creates an opportunity to conduct such research that would benefit both academics and professional project managers working on such projects. Hence the research questions introduced for the research problem is:

“What are the CSFs over whole life-cycle of dam engineering projects in Australia?”

#### 4. Candidate Critical Success Factors (CCSFs)

According to Khan, K et al. (2013), there is no universally agreed model or list of CSFs that can be used for all projects. In fact, many researchers have attempted to list CSFs, but it is impossible to list a definitive set of all CSFs for a successful dam engineering project from the literature. Therefore, in this research a list of CCSFs have been identified and listed from the literature so that the CSFs could be identified from the long list of CCSFs trying to make the input to the research as comprehensive as possible. Table 1 presents the list of CCSFs.

Table 1. List of CCSFs

CCSFs	References
Top management support	Cooke-Davis (2002); Hartman and Ashrafi (2002); Slevin and Pinto (1986); Ward (1995); White and Fortune (2002); Phua (2004); Iyer and Jha (2005); Baccarini and Collins (2003); (Osorio et al. 2014)
Project manager capabilities and commitment	(Chan, Albert and Chan (2004); Chua, Kog and Loh (1999); Jaselskis, E and Ashley (1991); Ogunlana et al. (2002); Shahid Tabish and Jha (2012); Yang et al. (2010)
Effective communication	(Bryde and Robinson (2005); Chua, Kog and Loh (1999); Doloi et al. (2012); Leung, Ng and Cheung (2004); Wang, X and Huang (2006); Yang et al. (2010); Osorio et al. (2014)
Adequate risk analysis and management	(Barber (2005); Cooke-Davis (2002); Wang, SQ, Dulaimi and Aguria (2004); Yun et al. (2015);
Effective scheduling	(Jaśkowski and Biruk (2011); Jha and Iyer (2007); Shahid Tabish and Jha (2012)
Clear scope and work definition	Chan, Albert P. C., Chan and Scott (2004); Doloi et al. (2012); Jha and Iyer (2007); Leung, Ng and Cheung (2004); Turner, J. R. and Cochrane (1993); Butler et al. (2004); Nguyen, Ogunlana and Lan (2004);
Effective technical review	Chua et al. (1997); Cooke-Davis (2002); Munns, Bjeirmi and Munns (1996)
Proper completion of previous phase(s)	Gunduz and Yahya (2015); Chua et al. (1997); Sanvido et al. (1992)
Build competent project team	Hyvari (2006); Khang and Moe (2008); Osorio et al. 2014; Pinto, J and Slevin (1989); Pinto, JK and Slevin, DP (1988); Turner, J and Müller (2005)
Authority of the Project Manager	Erling et al. (2006); Pinto, J and Slevin (1989); Pinto, JK and Slevin, DP (1988)
Monitor performance, project control and feedback	Hyvari (2006); Turner, J and Müller (2005); Yeo (2002), Baccarini and Collins (2003); Butler et al. (2004); Nguyen, Ogunlana and Lan (2004)
Adequate Resources	Hyvari (2006); Khang and Moe (2008); Pinto, J and Slevin (1989)



CCSFs	References
Realistic cost and time estimates	Pinto, JK and Slevin, DP (1988); Kerzner (2013); Pinto, J and Slevin (1989); Yeo (2002); Baccarini and Collins (2003); Chua, Kog and Loh (1999); Ofori (2013); Ihuah, Kakulu and Eaton (2014); Aneesha and Haridharan (2017); Ibronke et al. (2013)
Adequate change management	Wong and Tein (2003); Butler et al. (2004); Osorio et al. (2014)
Political support	Li et al. (2005); (Aerts et al. (2014); Ng, Wong and Wong (2010); Yuan et al. (2010)); Almarri and Boussabaine (2017)
Public support	Almarri and Boussabaine (2017); Almarri and Boussabaine (2017)
Stable economic condition	Zhang (2005); Chou and Pramudawardhani (2014); Solomon and Akinsiku (2012); Verhoest et al. (2015)
Effective problem solving and decision making	Baccarini and Collins (2003); Cheng (2002); Aneesha and Haridharan (2017)
Clear definition of roles, responsibilities and accountabilities	Frese and Sauter (2003); Chan, Albert P. C. et al. (2004); Beleiu, Crisan and Nistor (2015)
Teamwork	Baccarini and Collins (2003); Esmacili, Pellicer and Molenaar (2016)
Favourable weather condition	Mian, Humphreys and Sidwell (2004); Ihuah, Kakulu and Eaton (2014); Sunjka and Jacob (2013); AWUOR (2015); Tabish and Jha (2011); Chan, Albert P. C., Chan and Scott (2004)
Absence of bureaucracy	Nguyen, Ogunlana and Lan (2004); Tabish and Jha (2011)
Up to date technology utilisation	Nguyen, Ogunlana and Lan (2004);
Knowledge sharing	Nesan (2012); Davenport, De Long and Beers (1997)
Proper incentives and motivation	Chua, Kog and Loh (1999); Gunduz and Yahya (2015); Tabish and Jha (2011);

Each of the CCSFs is explained below:

#### *Top management support*

Top management support is one of the most cited CSFs but many top managers are still unaware of its importance on project success (Baccarini & Collins 2003; Madanayake 2014). The effect of top management support is wide and its effect covers a variety of project aspects from quality or user satisfaction to better communication, enthusiasm and involvement (Young & Jordan 2008). Adequate and timely access to resources is essential for effective execution of project processes and activities, and this is not possible without positive reaction to the resource allocation requests and support by the top management (Alexandrova & Ivanova 2013). Project managers are dependent on the authority, direction and support which are all somethings that the top managers have a great influence to provide the project manager with and should be convinced that the project is worthwhile to support it (Baccarini & Collins 2003).

#### *Project manager capabilities and commitment*

Technical, administrative, leadership and other project related skills of project manager is an important component during project processes and activities (Salleh 2009). Competence and commitment of project manager and how they manage project teams affect the project performance and outcomes (Marzooqi & Ahmed 2016). A study by Alexandrova and Ivanova (2013), showed that project manager capabilities and commitment was ‘extremely important’ for 80% of the respondents to achieve project success indicating the importance of this project

success factor. This study provided additional evidence supporting the previous studies that indicated project managers' skills and commitment is one of the most important CSFs over project life-cycle.

#### *Effective communication*

Numerous researchers in the area of project success have emphasised on importance of proper and effective communication for project success. Dam engineering projects are complex and cross-disciplinary making effective communication even more important. Effective and proper communication between teams members and other project parties leads to more realistic expectations, better relationships, less ambiguity and more effective teamwork (Dong, Chuah & Zhai 2004). Some communication methods such as face-to-face meetings might be more effective than other such as emails. Although all methods have advantages over others, combination of different methods should be used for more effective communication (Frank Cervone 2014). As dam engineering project involve many teams with different expertise and different organisations, 'effective communication' is certainly a factor that should be examined in exploring CSFs for such projects.

#### *Adequate risk analysis and management*

Adequate risk analysis is referred to in the literature as one of the potential CSFS for projects and is defined as effective identification and management of potential issues and problems that might undermine the success of a project. Risk analysis and management consist of making decisions on the available information on situations that may or may not occur (de Bakker, Boonstra & Wortmann 2011). The likelihood and consequences of the risks should be accurately determined to achieve adequate risk analysis leading to project success by improvement in project planning, budget and design related activities (De Bakker, Boonstra & Wortmann 2010). Raz, Shenhar and Dvir (2002) found out that risk analysis and management are more important and applicable to projects that are prone to have more associated risks. As dams are high risk projects with specific approach introduced to manage risks of these project in Australia, adequate risk analysis and management is chosen as a candidate CSF for this study.

#### *Effective scheduling*

Effective scheduling is another factor that affects many aspects of project success and has been widely cited by many researchers as a CSF for projects. Effective scheduling for different activities in organisations and projects has evolved over the years and become a vital activity that heavily affects success or failure of most projects undertaken in different industries (Brako, Joseph & Brako 2017). Effective scheduling is proper preparation of a detailed plan including actions and required steps of the work that needs to be performed during project process and determining what resources are needed, and estimating timeframe of activities (Van Eynde 2017). As an important component of projects, 'effective scheduling' is select as a candidate CSF for this study.

### *Clear scope and work definition*

Clear scope and work definition has an important role in achieving project success and this has been reflected in the literature numerous times (Butler et al. 2004; Nguyen, Ogunlana and Lan 2004). This is about determining precisely what is going to be the outputs of the project and determine the deliverables and all the required project work to support achievement of the successful delivery. It also includes general philosophy and mission of the project. If the project scope and work definition is ill-conceived, this would lead to poor work arrangements and wrong decision makings from the beginning of the project (Munns, Bjeirmi & Munns 1996). The work definition and project scope should be realistic and understandable (Dong, Chuah & Zhai 2004; Wateridge 1998). Adequate definition of the work and agreed-upon project scope lead to no or minimum changes in the project scope and work and teams efforts remain effectively and efficiently within the defined project scope throughout the project avoiding project overruns (Dong, Chuah & Zhai 2004). As an important factor that really matters in different contexts, 'clear scope and work definition' is chosen as a candidate CSF for this study.

### *Effective technical review*

All projects need a review component for technical matters that helps identify any technical gaps in project implementation (Joseph 2014 ). This is a well-defined continuous review of the project activities and outputs to find and fix the project technical defects (Chua et al. 1997; Cooke-Davis 2002; Munns, Bjeirmi and Munns 1996). This could be conducted by establishment of the project peer review group covering different areas of project technical practice. This could happen at different stages of project such as different milestones, completed tasks and near project completion. As dam engineering project are highly technical which need complex expertise, 'effective technical review' is chosen as a candidate CSF for this study.

### *Successful completion of previous phase(s)*

The way that previous phases of a project were delivered affects performance of the current phase. Many activities of the current project phase rely on the information provided in previous phases, hence, the success of previous phases has an important role in how well the project is delivered in a specific phase (Chua et al. 1997; Sanvido et al. 1992). The importance of having design phase completed properly before start of the construction phase of civil engineering project was shown by Chua, Kog and Loh (1999). As this study covers whole life-cycle of projects from planning to operation, 'successful completion of previous phase' seems to be a suitable candidate CSF to realise how importance of this changes as the project moves from one phase to another.

### *Build competent project team*

Build competent project team is another factor affecting project success which is widely mentioned in the literature. In a research by Alexandrova and Ivanova (2013), 70% of the respondents considered competent project team as 'extremely important' CSF and 'highly important' by another thirty percent of the respondents. Building competent project teams is about proper recruitment, selection and training of project team members. In order to build a

competent project team, the required skills, knowledge and qualifications should be determined based on project objectives and complexity; and project team should be selected wisely to ensure they have the necessary skills and commitment to perform their functions effectively (Baccarini & Collins 2003).

#### *Authority of the Project Manager*

Authority of the Project Manager is another factor that has been widely referred to as a CSF for different types of projects (Pinto and Slevin 1988). In a study by Spalek (2005), it was shown that high authority of the Project Manager has 85% influence on the project success. As the project manager is the representative of organisations and senior management, authority of the project manager is the power that enables the project manager to act in the name of them (Pollack & Algeo 2014). This includes the authority of decision making related to team and project activities. In addition to being committed, the project manager should have enough control over the project in order to be able to make decisions, develop plans, and make necessary changes during the course of the project (Baccarini & Collins 2003).

#### *Monitor performance and feedback*

‘Monitor performance and feedback’ is about comprehensive control of information during project implementation and to keep eye on performance related to targets, milestones and team members in order to keep the project on the right track. Proper control and feedback system provide adequate monitoring enabling project managers to compare project performance and achievements with the project objectives (Baccarini & Collins 2003; Gioia 1996; Jaselskis 1990; Jiang, Klein & Balloun 1996). This will lead to higher chance of project success as projects managers become able to anticipate problems and undertake preventive or corrective actions making sure that project deficiencies are not overlooked (Baccarini & Collins 2003).

#### *Adequate resources*

‘Adequate resources’ is another factor affecting project success mentioned in the literature. Adequate resources such as funding, people, equipment, facilities, and time, which are important to ensure success of projects, should be provided, maintained and managed properly over life-cycle of the project (Baccarini & Collins 2003). As important expertise and capital for organisations and projects, project team members and other project participants must be provided with the best possible resources enabling them to work effectively and collaboratively (Mistry & Davis 2009). As problems and obstacles arise during project implementation, the presence of adequate resources, in particular funding, help project managers and team members overcome difficulties and deliver projects successfully (Yeoh, Koronios & Gao 2006). All project activities need adequate resources assigned to them and dam engineering projects are not exceptions.

#### *Realistic cost and time estimates*

‘Realistic cost and time’ estimate specially in early stages of projects has been mentioned in the literature as an important CSF. The importance of realistic cost time estimations was described by Arestegui Carvajal (2014) for achieving successful complex projects; in his case:

underwater tunnel projects. Every project manager is dependent on realistic cost and time estimates to allow for successful cost management and scheduling (Torp & Klakegg 2016). By breaking down the process into little tasks and steps, it is possible to estimate the time and cost precisely to avoid preventable failure of the project later in the project.

#### *Adequate change management*

A project manager should keep track of all changes that happen over the implementation of the project having a proper approach to cope with them by using a formal and useful change management principles and processes in place (Dong, Chuah & Zhai 2004). As project progresses, changes in the scope of work, team members and work condition and other usual changes happen and the ability to respond effectively to the changes has an important role in success of project (Wateridge 1998). Levasseur (2010) examined project success rates and showed the chance of project success increases significantly having an established change management system. Projects are core elements of different type organisations and successful continuation and delivery of them can be ensured through a proper change management (Ghanim, Munassar & Dahlan 2013). As a CSF frequently mentioned in the literature (Wong and Tein 2003; Butler et al. 2004; Osorio et al. 2014), ‘adequate change management’ is chosen as a CCSF for this study.

#### *Political support*

Given the fact that many projects that require government funding are influenced by ruling parties, support from political figures and parties are important (Jacobson & Ok Choi 2008). Public project are heavily influenced by political situation of the day and hence need to be pinpointed by political support (Garbharran, Govender & Msani 2012). This could be achieved by spending the time up front to have a proper strategy to sell the project to influential political figures to avoid years of fight against the opposition that could be avoid from the start. In the study by Alhashemi (2008) on public-private partnership projects, political support was the main factor among the factors examined for project success. Other researchers have also mentioned ‘political support’ as a CSF (Li et al. 2005; Aerts et al. 2014; Ng, Wong and Wong 2010; Yuan et al. 2010); making this a suitable CCSF for this study.

#### *Public support*

This has become a fact in modern era that success of development and implementation of projects require a wide public support (Kušljčić & Marenjak 2013). Support from society helps the project achieve its objectives as it increases the chance of final approval of the project and possibly funding. A successful project needs to receive support of the public stakeholders which could be achieved by the help of effective communication to receive their feedback and concern regarding the project (Tran 2016). As many benefits of projects are quantified based on how much the society is willing to pay for it during operation, it is important to attract support for public projects from wide range of public stakeholders and the society in local, state and national scale (Garbharran, Govender & Msani 2012).

### *Stable economic condition*

Stable economic condition refers to the constant positive macroeconomic condition and absence of unusual economic fluctuations. In a study Sharaffudin and Abdullah (2017), public agencies considered a stable economic condition as the most important CSF for their projects. Constant growth and low inflation, reasonable interest rates and friendly economic policy for investors contribute to stable economic condition subsequently increase the chance of project success (Cheong Yong & Emma Mustafa 2012). Many other researcher (Zhang 2005; Chou and Pramudawardhani 2014; Solomon and Akinsiku 2012; Verhoest et al. 2015) have also mentioned ‘stable economic condition’ as a CSF for projects, making this a suitable CCSF for this study.

### *Effective problem solving and decision making*

‘Effective problem solving and decision making’ has been referred to in the literature as an important project success factor (Baccarini and Collins 2003; Cheng 2002; Aneesha and Haridharan 2017). This using suitable methods for finding solutions to the problems that the project faces and adaptation of an approach to select course of actions among different decision alternatives to come up with the best decision. Knowing how to be competent in problem solving and decision making is really important for projects and is largely achieved by effective utilisation of knowledge resources in the project team (Lin et al. 2015). Despite the fact that huge amount of effort is spent on careful planning of projects, it is almost difficult to predict all problems that might happen during a project and it makes it vital to be responsive and capable of applying appropriate problem solving and decision making processes for project (Baccarini & Collins 2003).

### *Clear definition of roles, responsibilities and accountabilities*

‘Clear definition of roles, responsibilities and accountabilities’ is an important factor enabling project to achieve success (Jawad, Ledwith & Panahifar 2018). Successful team building is not just about choosing the right people for the roles but also knowing what they have to do and when they have to do it leading to increased efficiency of teams (Beleiu, Crisan & Nistor 2015). Before building teams, it is important that roles and responsibilities are defined properly because it is not possible to find the match person for each job without knowing exactly what kind of responsibilities we are looking for. Project manager is responsible for defining to set the roles, responsibilities and accountabilities to determine what is expected from the job of the people in different positions (Frese and Sauter 2003; Chan, APC et al. 2004; Beleiu, Crisan and Nistor 2015).

### *Teamwork*

Project members must work together as a team. To create a teamwork between project team members, a sound working relationship and realistic expectations are needed (Baccarini and Collins 2003; Esmaeili, Pellicer and Molenaar 2016). Project team members should share the same goal, have strong team working ethics, be compatible and work in harmony with each other (Baccarini & Collins 2003). Working in teams in essential part of project based working

environment. Teamwork is effective and efficient combination of actions by different people of a project. Teamwork helps increase efficiency, create new ideas, improve communication, share the workload and bring learning experience.

#### *Favourable weather condition*

Many researchers especially in construction industry have referred to 'favourable weather condition' as an important CFS that project managers have no control (Mian, Humphreys and Sidwell 2004; Ihuah, Kakulu and Eaton 2014; Salleh 2009; Sunjka and Jacob 2013; AWUOR 2015). Dam engineering projects heavily deal with river system and are affected by weather condition. It is more important when the real construction works start as different weather condition such as dry and cold weather, floods, winds and thunderstorms that impact on the project. It is also important that climate situation is favourable during operation and different scenarios for climate change may affect operation.

#### *Absence of bureaucracy*

Bureaucracy is unnecessary work that significantly complicated administrative process of projects and is caused by excessive reliance on rules and regulations (Kwiatkowski 2017). It leads to slow progress and project implementation and should be avoided in the project by simplifying the procedures (Amendola et al. 2016). According to (Huhtala, Ketola & Parzefall 2006) innovative and successful organisations do not organise and structure themselves bureaucratically. Most employees and project team members prefer a flexible organisation structure and absence of bureaucracy for an empowering work environment (Larsen 2002).

#### *Up to date technology utilisation*

'Up to date technology utilisation' plays an important role in modern work environments (Dong, Chuah & Zhai 2004; Hartman & Ashrafi 2002). There should be proper technical capability in the project to effectively support the project implementation and delivery (Dong, Chuah & Zhai 2004). Technology has an important role in project management as the current work environment is totally technology-enabled using the latest technological tools for different project activities. Using the latest technologies could help effective and efficient project management practice. Some other researchers (Nguyen, Ogunlana and Lan 2004) have also referred to 'up to date technology utilisation' as an important success factor making this a suitable candidate for dam engineering project that rely heavily on technologies due to their technical complexity.

#### *Knowledge sharing*

Knowledge sharing is an exchange process in which information, skills and expertise are shared among project team members, community or organisation (Hasmath & Hsu 2016; Serban & Luan 2002). Technology plays an important role in knowledge sharing along with culture, trust and incentives (Cabrera & Cabrera 2002). Knowledge sharing has been expressed as being highly correlated with project success. Motivating individuals to create, share and use knowledge has been mentioned in the literature as an important CSF for projects (Davenport, De Long & Beers 1997; Nesan 2012). Nesan (2012) emphasised on importance of speed in

successful knowledge sharing stating that fast access to the information could be facilitated by proper use of information technology. As dam engineering industry projects are complex with various involved expertise which require share of knowledge between project parties and teams, knowledge sharing is chosen as a CCSF for this study.

#### *Proper incentives and motivation*

An incentive is a measure to achieve motivation for an individual or teams to undertake actions, improve performance and contribute to success. Having an incentive-based system is considered to be a key project monument activity (Armstrong 2015). Motivation is the reason behind actions by people and is associated with their desires and needs (Burton 2012). Ryan and Deci (2000, p. 54) stated that “orientation of motivation concerns the underlying attitudes and goals that give rise to action”. People become motivated to achieve certain personal and organisational goals (Burton 2012). ‘Proper incentives and motivation’ have been mentioned in the literature as an important CSF (Chua, Kog & Loh 1999; Gunduz & Yahya 2015; Tabish & Jha 2011) making this a suitable CCSF for this study.

### **5. Conclusions**

Based on literature review findings presented in this paper, undertaking research to identify CSFs based on the list of CCSFs of this paper and present a success paradigm on dam engineering projects in Australia is recommended and will be the aim of the PhD research project of the authors. The dam engineering projects are required to achieve certain goals based on the defined objectives of the project such as meeting the budget, time and stakeholder satisfaction. As there is a lack of prior research on success of this type of projects, the findings of this research could extend the existing body of knowledge to cover dam engineering industry. The findings of this research could assist in addressing these issues and make informed decisions in respect of dam engineering industry projects success. The study will enable project managers to have a much better understanding of what contributes to success of dam engineering industry projects in Australia.

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# Exploring Safety Monitoring Practices on Construction Sites in Ghana

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## Abstract:

The Safety issues are not entirely secluded to any one country. It is a global problem and so requires global coordination to find a remedy to help monitor safety on construction sites. This paper explored the safety monitoring practices on construction sites in Ghana. The research instrument and the sampling technique adopted for the study were questionnaires and purposive sampling approach respectively. 84.13% response rate was retrieved from the targeted population consisting of the construction sites of good standing companies in Ghana. Means score Analysis was employed to rank the Safety monitoring practices and Kendall's coefficient of concordance was used to assess the level of agreement on the findings. The results indicated that having "toolbox" safety talk daily was the most frequent safety monitoring practice adopted by the construction operatives on sites. The Kendall's coefficient of concordance for the test was 0.684, which depicted that there is a level of positive fair strong agreement between the variables for the safety monitoring practices, thereby, the respondent strongly agreed fairly with the variables. Based on the findings, the results from this paper helps to shed-move light of the causes of the poor Safety performances on Ghanaian Construction Sites. The inadequacy of safety monitoring practices on Construction needs to be future studied to help improve safety performance.

**Keywords:** *construction site; efficient; monitoring; practices; safety*

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## 1. Introduction

In this era of globalization, there is the likelihood that the world's population would double in the next 40years (Berry and McCarthy, 2011). For the construction industry, this is good news because these extra people will need houses, schools and workplaces etc. in relation to infrastructural developments (Berry and McCarthy, 2011). However, Hinze (2002) added that, most importantly, some of these people will branch into construction as their professions, which means that the construction industry should be made more attractive and accident -free zone as much as possible for the new entrants. Safety is particularly of high significance to the construction industry. This, particularly, has remained a major area of concern as the construction industry is listed amongst industries highly exposed to occupational hazards and accidents (Hinze, 2002). Berry and McCarthy (2011) asserted that the years have seen significant transformative improvements in performance, on safety to be exact; regardless, this industry remains one of the highly hazardous industries as compared. Berry and McCarthy (2011) concluded that the fact remains and points to the construction industry sitting atop as one of the elite dangers and accident-prone industries as evident from yearly statistics on injury and fatalities. This statistic is more serious in developing countries. Construction workers'

predisposition to fatal injuries overshadows the national fatality three times. Its rate in injuries is 50% severer compared to the injury rates encountered in other industries (Charles et al., 2007). Hinze (2002) and Vredenburg (2002) conducted studies which revealed that Safety can be improved if construction workers change their attitude towards safety practices and incentive schemes are instituted to serve as motivation. One can deduct from the prevailing reality that these proposed solutions have not been given needed attention and effort to eradicate if not mitigate unsafe conditions on site (Charles et al., 2007). The most germane concern, in this case, is for employers and their employees to prioritize alleviating occupational injuries on construction sites (Gittleman et al., 2010). This study, therefore, seeks to explore safety monitoring practices that are capable of helping to alleviate occupational hazards and injuries on construction sites.

The alarming injury and fatality rates of the construction industry are closely related to the hazards and risks faced during construction activities. These include such activities as working at higher altitudes, working with moving plant and inhabited areas, and working on installing services both underground and on the surface (Hoonakker et al., 2005; Gittleman et al., 2010; Biggs et al., 2013). In response to these risks, injuries and fatal accidents, the pursuit is on for better safety conditions and performance in the construction industry (CRC Construction Innovation, 2007; Hon et al., 2012). In the construction industry, all the aforementioned causes may apply. According to (Hon et al., 2012), most construction workers are unskilled labourers and therefore it becomes very difficult in implementing the measures that could help curb this situation. A myriad of research findings has inextricably linked accidents on construction sites to negligence, carelessness, in adherent behaviour to professional and safety protocols on site (Hoonakker et al., 2005). This paper established a solid connection between workers' safety consciousness and attitude to a safe construction site. Moreover, actors' perception about risk, risk management, established procedures and rules on safety, including workers' cultural background have been found to greatly influence their attitude and consciousness of safe conduct (Hassan et al., 2007; Fogarty and Shaw 2010). Differing perceptions, behaviours and actions exhibited by construction workers and operatives have led to serious accidents on sites and have been linked to different cultural backgrounds. This has made it imperative that the behaviours, perception and cultural influences of construction workers towards safety are put under critical lenses. It is with this backdrop that this paper seeks to look into the various monitoring of the safety of operatives on construction sites in Ghana. This paper then explores safety monitoring practices on construction sites.

## **2. Literature Review**

### *2.1. Construction in Ghana*

The paper looks at the issues of Safety practices in the construction industry. The Construction industry in Ghana has high accident rates due to the nature of the work, management system, equipment used in the process, techniques used to perform the tasks, speed of the work and other relevant factors (Niskanen and Saarsalmi, 1983). Issues on safety are and have remained and it is still a major concern to the industry. Addo-Abedi (1999) revealed that construction businesses in Ghana are family owned and operated accordingly. This implies is

that such businesses having an employee number exceeding 200 is extremely unusual. In the regard, they can be all categorized under Small Medium Enterprise (SME) having to possess similar qualities as they do. Although, safety is a major concern to both developed and developing nations, most developed nations have managed to reduce the effect of accidents in the industry (Hämäläinen et al., 2006). Unfortunately, this puts developing nations behind as is the case in many aspects. The Sub-Sahara African countries are especially lagging behind the fight to secure safe condition for workers in the construction industry. Industrialization is likely to further aggravate this canker which, as it stands, is already at an escalated level in developing countries. (Hämäläinen et al., 2006). That notwithstanding, it is still a targeted goal of several construction companies and businesses to embraced a zero-accident policy, to reach it. Many of these companies have proceeded to execute effective practices that ensure safety (Hinze and Wilson, 2000). These accomplishments have been made possible because of the awareness created on the dangers posed by the industry's activities, and the focus and effort invested in securing a safe working environment. In spite of how critical the construction industry to the developing economy, its leaders and policymakers have not given it needed attention to it (Anaman and Osei-Amponsah, 2007).

Ghana's construction industry records the highest number of occupational fatalities when compared to other industries in the country. 56% of the total 902 occupational injuries and accidents recorded in the 2000 result in deaths. This denotes 77.6% of every 100,000 workers lose their lives from undertakings onsite (International Labour Office, 2012). In proper context, 1.5% of every 1,000 accidents in the industry was fatal as recorded by the European Union (EU) accidents statistics (European Commission, 2002). It is worthy of note that several accounts of site deaths in most developing nations are never reported and as such never accounted for in statistical data. This makes the factual stats a scary prospect with developing countries (Colak et al., 2004). This then requires a critical look at the operatives involved in the construction activities on site.

## *2.2. Construction Operatives*

The construction site is a very important place, as a considerable number of workers are involved in its activities. Employment in a construction site can be categorized into three groups; "Management and technical" workforce, "Skilled" workforce and "Semi-skilled and Unskilled" workforce. Personnel with high educational qualifications, usually graduates, trained to design, manage and instruct the construction processes can generally be identified as Management and technical" workforce (Almen et al., 2012). Persons who possess extensive knowledge and experience in their construction activities or profession are identified as "Skilled" workforce. "Semi-skilled and Unskilled" workforces are the site labourers with little or no construction knowledge (Almen et al., 2012). Generally, all skilled, semi-skilled and unskilled workers are at risk of being injured, death or various illnesses in a construction site, although the level of risk varies with activities they are engaged in (Almen et al., 2012).

Workers on construction sites are, generally, exposed to an excessive risk of being injured at work (Almen et al., 2012). Pungvongsanuraks et al. (2010) elicited that the construction industry is unique and complex compared to other industries. It involves a wide range of



construction materials and products, building services, manufactures, contractors, sub-contractors, design, operation, and refurbishment services. These complexities put the industry amongst the few most perilous industries that record a high rate of accidents. International Labour Office (2012) explains that an employer needs to have safety norms and standards; there should be safety practices in construction sites to be followed by the employer. Effective safety management aims at creating a safe working environment to secure an occupationally safe job, and to increase the awareness of workers on the issue of safety. In recent years, many developed countries have taken safety as an important management issue of construction projects, especially, personal safety (Chen et al., 2011). Adequate training of personnel in the construction industry is expected to increase their perception of safety at workplaces. In recent years, there has been interesting in improving the safety training at workplaces to increase employee motivation, awareness and safety performance in the construction industry. It is important to ensure that every new employee on the project site is given an appropriate orientation regarding safety inspections (Belel and Muhmud, 2012). It is the responsibility of every construction worker to identify unsafe conditions and behaviours and try to correct them (Belel and Muhmud, 2012).

### *2.3. Conceptualizing Construction Safety*

Safety in construction sites is needed to be highly considered in order to reduce the risk of being injured at work. Safety is also identified as one of the major factors affecting the image of the project manager and the organization (Grandjean., 1983). Safety, health and welfare on construction sites, a training manual published by the International Labor Office in Geneva, International Labor Office (2012) posits that high rate of accidents occurs in the construction industry than in other manufacturing sectors. Possibly because the construction industry is an amalgam of itinerant workers, many of who are not conversant with the construction processes, others are self-employed; but ultimately, a large number of them are seasonally employed. In addition, workers are exposed to bad weather and involved in many different trades and occupations. However, the manual published by International Labor Office in Geneva International Labor Office (2012) emphatically stated that the work in concern should be made safe and all existing conditions on site should mitigate threats and dangers to life and should enhance professional skills. International Labor Office (2012) explains that an employer needs to have safety norms and standards; there should be safety practices on construction sites to be followed by the employer. Effective safety management should create a safe working environment, a job free of dangers and should incite a conscious awareness in workers. In recent years, many developed countries have considered safety as one of the important management issues of construction projects, especially, personal safety (Chen et al., 2011). A study by (Abdule et al., 2003) revealed that there are two hazards that are common on construction site and are a major cause of physical injury. These are equipment such as scaffolds, power-driven equipment, ladders, equipment for excavation purposes. Other injuries can also be caused by noise, vibration, radiation extreme temperatures as a result of this mechanical equipment. Noise has been identified as one of the major risks on construction sites that can cause hearing loss according to (Archer, 2003).

Another hazardous chemical such as asbestos, welding fumes, spray paints, cutting oil mists, solvents and hexavalent chromium have also been identified (Pendlebury et al., 2006). Construction workers consider dust as a major chemical hazard. In addition, workers consider asbestos, cement and adhesives or solvents, to be the materials that can adversely affect their safety (Argrilla, 1999). Both small and medium-sized firms, as revealed from research findings, encounter several hindrances to establishing formal systems in their aim to create systems securing safety in construction works (Eakin et al., 2000; Mayhew, 2000). It is then an objective of the study to explore safety monitoring practices on construction site.

#### *2.4. Safety Monitoring Practices on Construction Site*

Managing a project successfully means not just executing it according to specifications within the stipulated time and with budgeted funds but also with optimum safety (Belel and Muhmud, 2012). Charezehi and Ahankoob (2012) added that it is not impossible to task to secure high safety performance in construction. To improve site safety, contractors in construction sites are entreated to create a working policy to enhance safety administration, create an avenue for safety training for its workers, amongst others. They are as well entreated to undertake regular meeting on safety at the project level, ensure adequate measures on safety, making available personal protection equipment (PPE), put up safety signs and posters, undertake regular safety inspections, establish a system for acknowledging and awarding safe conduct, etc. (El-Mashaleh et al., 2010). Mahalingam and Raymond (2007) identified that mandatorily enforcing measures like fining, as an effective approach to enhance safety performance on site. The important attitudes for increasing safety performance and declining risk are to identify root causes of construction hazards and accidents, and manipulating proper precautionary tools and equipment related to the type of construction project and site condition (Charezehi and Ahankoob, 2012). Charezehi and Ahankoob (2012) explained the contributing factors to health and safety development in construction. These include:

#### *2.5. Safety Analysis*

Chao and Henshaw (200) posited that Job Safety Analysis is a practical method for identifying, evaluating and controlling risks in industry procedure. Identifying future safety risk at the design stage to a large extent can reduce the loss of life and property. Cooperation between the designer and the client is a panacea for safety risk for each project option. This approach can be extended to other stakeholders of the project such as the public, the users and the environment. Safety Risk Analysis, when used is there to identify acceptable risk from dangerous activities. The safety Risk level is classified by company, the severity and probability and ranked for further analysis. Mitigation measures are therefore put in place to reduce risk (Charezehi and Ahankoob, 2012). The Construction Job Safety Analysis (CJSA) method generates a large knowledge-based describing all possible loss-of-control events in construction.

## *2.6. Safety Auditing*

It is important to monitor, measure, review and document issues regarding safety as part of identifying safety standards on the construction sites. A safety audit collates all such information, thus enabling the project supervisors to plan, organise and control existing and upcoming site work in a safe and efficient manner. According to (Design Buildings, 2019), safety audits are carried out to assess health and safety processes on construction sites, considering; legislative requirements, industry best practice, and the contractor's own health and safety management systems. Design Building (2019) emphasized that safety audit can demonstrate a proactive approach which is being taken to safety, can help to improve ways of working and ensure procedures are being followed, as well as demonstrating compliance with regulations such as the Construction (Design and Management) Regulations 2015, which require reasonable steps are taken to ensure the health and safety arrangements made for managing the project are maintained and reviewed throughout a project. Regular audits can form a crucial part of the project management process and may be undertaken by in-house personnel, or by an independent auditing body.

## *2.7. Safety inspections*

According to (Ochoa et al., 2011), site inspections are usually key activities in construction project management. Ochoa et al. (2011) added that the ultimate aim of conducting site inspection is to analyze the status and conditions of construction components or elements, so as to approve, reject and modify such element based on the analysis conducted. Site inspections are the most effective means of identifying hazardous conditions at the work site, and it usually requires constant monitoring and observation to keep ahead of safety issues (Safety Management Group, n.d). Safety inspection helps to identify hazards and provide opportunities to fix problems before injuries and accident can occur (Safety Management Group, n.d). Site Inspection, therefore, is an effective monitoring practice to help ensure safety on construction sites.

## *2.8. Safety records keeping*

Safety records are usually information used to support safety claims, and also demonstrate the degree of acceptability of the safety performance on construction sited (SKYbrary, n.d). Safety records are to be maintained throughout the construction operation. Construction Safety records are also needed to provide data and traceability which can help to identify and solve actual safety issues. It is very important to identify the safety records for each construction process, making sure that only that critical information to safety is maintained (SKYbrary, n.d). Also, with regards to international, as well as national regulations and standards, it may be required to provide safety records as a basis for providing workers with safety assurance (SKYbrary, n.d). Being able to have efficient safety records is capable of ensuring effective safety monitoring practice on construction sites.

### *2.9. Toolbox safety talks*

Toolbox safety is brief meetings on Safety instructional sessions (Eggerth et al., 2018), usually held on the construction sites. According to (Jones, 2011), toolbox safety talks are usually great practices on construction site that present a way to strengthen safety basic, focus on high risk cases on sites and also to make workers aware of the changes to the construction job sites, as well as working conditions that may have befallen since their last shift. Jones (2011) added that site supervisors must be sure to briefly discuss any injury or accident that have happened and how they could have been prevented. Eggerth et al. (2018) presented his study findings on the effectiveness of toolbox safety talks: to increase OSH knowledge, to increase the impact of training safety, and to improve worksite safety climate. Mosaic (2016) contributed to the effectiveness of the toolbox meeting by ensuring that all workers participate and are engaged in the toolbox talk. Knowing and understanding the material delivered is really important too, thus ensuring good delivery (Mosaic, 2016). The toolbox safety talks, when done properly, can help to effectively monitor safety on construction sites.

### *2.10. Accident meetings*

Workers' safety should be prioritized among all activities on construction sites of every construction company. Jones (2011) posited that every site meeting should be conducted to educate the workers on safe work practices, and also to ensure compliance with regulations on safety. Safety meetings are significant in helping to build a strong safety culture, as well as reinforcing the company's commitment to protecting the lives of workers on sites (Jones, 2011). He again suggested that safety meetings are usually the perfect time to make known to new safety policies and procedures that are yet to be implemented, as well as safety rules and regulations which can help workers to be compliant with the Safety standards.

### *2.11. Accident investigation*

According to (Abdelhamid et al., 2003), accident investigation in the construction industry helps identify the types of accidents occur and how they occur. This is due to the hazardous nature of construction works. Brown and Choong (2005) convincingly protested that accident investigation techniques should be firmly dependent on the theories governing the causation of accident and human error. This can then help in better understanding of the relation between the antecedent human behaviour and the accident at a level enabling the root causes of the accident confirmed. Safety Management Group (n.d) asserted that incidents involving no injury or damage of property should be investigated on the construction site to help determine the hazards that should be corrected. Accident investigations are usually carried out by safety professionals who will visit the scene on site to obtain facts. An efficient accident investigation and report on construction can help to effectively monitor safety.

## **3. Research Methodology**

The objective of the study is to explore safety monitoring practices on the construction sites. In accomplishing the fore-stated objective enumerated in this paper, a logical and sequential structure was followed. Desk research which was based on library-related books, scientific journals and periodicals and internet research, as well as a web-based search, were

used to review existing related literature. This study adopted the quantitative research method. Questionnaires were sent to construction operatives (workers and professionals) on construction sites. The population for the study constituted the construction operatives including workers and professionals in the construction industry in Kumasi Metropolitan. The study then adopted a purposive sampling technique to select the construction operatives. A response rate of 84.13% was achieved. The collected data from the questionnaires were coded and analyzed using the Statistical Package for Social Sciences (SPSS) current version and Microsoft Excel. Tables were used for Interpretation of data to get the valid meaning to the responses. Means score Analysis was used to rank the dependent variables obtained to establish how they are prioritized by the construction operatives. Kendall's Coefficient of Concordance was used to reveal the level of agreement between the variables.

#### 4. Findings and Discussion

The paper achieved a response rate of 84.13% from the responded questionnaires sent the targeted population of construction operatives. A response rate of approximately 35% is known as academically satisfactory for studies aiming at the workers on construction sites (Baruch, 1999). In other to ensure authenticity and credibility in the data collected, it was very important to analyze the background of the respondents. It helps to ensure trustworthiness and confidence in the outcome of the research study.

Table 1: Background Analysis of Respondents

Variables		Frequency	Percentage, %	Cumulative percentage, %
Gender	Male	51	96.2	96.2
	Female	2	3.8	100.0
	Total	53	100.0	
Category of operative in the firm	Project manager	25	47.2	47.2
	Health and safety officer	14	26.4	73.6
	Others	14	26.4	100.0
	Total	53	100.0	
Academic background	Diploma	3	5.7	5.7
	Bachelor's degree	42	79.2	84.9
	Master's degree	8	15.1	100.0
	PhD	0	0	100.0
	Total	53	100.0	
Professional certificate	Yes	9	17.0	17.0
	No	44	83.0	100.0
	Total	53	100.0	
Years in the firm	Less than 5 years	12	22.6	22.6
	5-10 years	19	35.9	58.5
	11-20 years	14	26.4	84.9
	Above 20 years	8	15.1	100.0
	Total	53	100.0	

Source: (Field Survey, 2018)

The purpose of the gender is to help show the number of males and females who responded to the questionnaires. This is shown below in Table 1. The results indicated in Table 1 shows that, out of 53 respondents, 96.2% which is 51 were males and 3.8% which is 2 were females.

This means that more males in the firm responded more than the females in the firm. This could be as a result of the high number of males in the construction Industry, that gender in-balance.

Identifying the category of workers in the firms will make sure the targeted respondent actually answered the questionnaires. The validity of the information will depend on the information retrieved from this part. Table 1 indicates that out of 53 responses, 47.2% were project managers, 26.4% were health and safety officers and 26.4 % were from other workers.

On the academic background of the respondents. Out of the 53 responses, 5.7% were having a diploma certificate, 79.2% with bachelor's degree certificate and 15.1% having master's degree certificate with no Doctor of Philosophy.

This part shows the professional background of the construction operatives in the industry, Kumasi Metropolis. Respondents were asked whether they were holding a professional certificate, with yes or no response. This can also add to the credibility of the data collated. Table 1 shows that 17% of the respondents were having a professional certificate from professional bodies. whilst 83% were having no professional certificate. This reveals that the majority of the construction operatives were having no professional certificate.

The number of years with the Firm will have a great impact on the authenticity and credibility of the information given out. Table 1 also shows how long workers have been with the firm. Table 1 shows that, out of 53 responses collected from the firms, 22.6% have been in the firm less than 5 years, 35.9% have been in the firm 5 to 10 years of experience, 26.4 % have been in the firm 10 to 20 years and 15.1% for more than 20 years. The table then concludes that Majority of the respondents have been in the firm 5 to 10 years, thereby showing how reliable the information is.

#### *Discussion on Safety Monitoring Practices Adopted on the Construction Site*

The objective of the paper was to identify the safety monitoring practices adopted on the construction sites. The practices were identified, and respondents were asked to rank the practice based on the 5-point Likert scale ranging from 1- never, 2-seldom, 3-sometimes, 4-frequently and 5-always. Means Score Analysis was employed to rank the dependent variables obtained to establish how they are prioritized by the construction operatives. The ranking of the variables is shown in Table 2. Kendall's Coefficient of Concordance was used to reveal the level of agreement between the variables. The level of agreement portrayed is shown in Table 3.

Table 2: Safety Monitoring Practices Adopted on the Construction Site

Safety Monitoring Practices	Mean	Standard deviation	Ranking
Having “toolbox” safety talks daily	4.43	0.605	1
Conduct weekly safety inspections	3.64	0.710	2
Holding safety meetings regularly	3.64	0.762	3
Recording of near-miss accident	3.55	0.867	4
Accident investigation	2.70	0.774	5
Safety record keeping	2.64	0.787	6
Having safety analysis regularly	2.02	1.028	7
Safety record review	1.91	0.946	8
Collecting safety data with tally sheet regularly	1.64	0.982	9
Safety auditing	1.49	0.823	10

Source: (Field Survey, 2018)

Table 2 depicts the variables for the safety monitoring practices ranked based on the responses from the construction operatives on construction sites, Kumasi Metropolis. These: Having “toolbox” safety talks daily (4.43), conduct weekly safety inspections (3.64), holding safety meetings regularly (3.64), recording of near-miss accident (3.55), Accident investigation (2.70), Safety record keeping (2.64), having safety analysis regularly (2.02), Safety record review (1.91), Collecting safety data with tally sheet regularly (1.64) and safety auditing (1.49). From the Table 2, having toolbox safety talks daily was ranked the first (1st) with mean score 4.43 by the respondents, whilst the safety auditing was ranked tenth (10th) with a mean score of 1.43. The paper revealed that having toolbox safety talks daily was the most frequent practice adopted on the construction sites in Kumasi Metropolis. This is consistent with the work of Hislop (1991) when he proposed toolbox safety talks as an important programme to help ensure efficient interactions with operatives daily on site. Olson et al. (2016) also supported the idea of toolbox safety talks by embarking on daunting empirical research because the toolbox meeting is capable of preventing construction fatalities. They again buttressed that, if employers opt for safety meetings, all available employees must attend, and meetings must be held at least once a month and/or at the beginning of any job lasting more than a week. The meetings must include discussions of safety issues and accident investigations, causes, and the suggested corrective measures. To continuously be consistent with the findings of this paper, Mosaic (2016) contributed to the effectiveness of toolbox meeting by ensuring that all workers participate and are engaged in the toolbox talk. Knowing and understanding the material delivered is really important too, thus ensuring good delivery (Mosaic, 2016). This requires that toolbox safety talks should be prioritized.

Table 3: Test of Concordance using Kendall's coefficient of concordance

Population, N	53
Kendall's W <sup>a</sup>	0.684
Chi-Square	326.128
Df	9
Asymp. Sig.	0.000

a = Kendall's Coefficient of Concordance

Table 3 shows the level of agreement between the variables for safety monitoring practices. Kendall's coefficient of concordance for the test is 0.684, which shows that there is a level of positive strong agreement between the variables for safety monitoring practices. The findings portray that the variables on the table are statistically significant because the table has  $p(\text{Sig}) < 0.05$ . with Kendall's coefficient of concordance of 0.684, it shows that respondents agree with each other to a reasonable but not super high extent. This then contributes to the fact that all the variables are agreed fairly to be safety monitoring practices on construction sites.

### *Theoretical And Practical Implication*

The contribution of this study can be stretched to the other sectors from the construction industry including safety policymakers. The safety monitoring practices have been vividly explored as a research gap to be catered for in the construction industry. The study revealed that having toolbox safety talks daily is the most frequent practice adopted on construction sites and should be encouraged. The contributions of the study will be beneficial to construction operatives on site as it will help to invest in organizing efficient safety toolbox meeting to help solve safety issues before the commencement of activities on the construction site. There is a need for efficient toolbox meeting to help deal with construction fatalities as asserted by (Olson et al., 2016). This paper has contributed to filling the research gap by making it known to the construction industry, both globally and locally, the safety monitoring practices to be encouraged on site, as well as revealing that having toolbox safety talks daily can help in monitoring safety on construction sites.

The paper further seeks to enhance the understanding of safety monitoring in the construction industry, especially on construction sites, by making it available the safety monitoring practices. Theoretically, the study has revealed toolbox safety talk daily as a prioritized safety monitoring practice that needs to be encouraged on construction site. This is an important theoretical gap the study has contributed, and it is reliable for further studies on safety in the other sectors, both the public and the private sectors.

## **5. Conclusion and Further Research**

The findings as seen throughout this research has pointed out the definition of safety issues, which has provided integrating focus to explore the safety monitoring practices on construction sites. The study finally concluded that toolbox safety talk should be encouraged daily on site to enable effective monitoring of safety practices and should be a priority among several other options. The findings of the study will be valuable to construction operatives on site as it will help to invest in organizing efficient safety toolbox meeting to help solve safety issues before activities begin on site. Olson et al. (2016) made it known that there is a need for efficient



toolbox meeting to help deal with construction fatalities. This paper has contributed to the research gap by making it known to the construction industry, both globally and locally, the safety monitoring practices to be encouraged on site. This paper, therefore, encourages the use of toolbox safety talks on site, as it is an efficient way of monitoring safety practices on site. It is recommended that further research is undertaken on the safety monitoring programme on construction sites to help create the awareness of safety monitoring practices of operatives.

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# Necessity of Integrating the Maintenance Stage with the Early Stages of Projects

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## Abstract:

Road is one of the basic infrastructures for social and economic development of any society. As the significance of road networks is beyond national boundaries, its expansion and enhancement are vital for increasing economic performance of any country. Poor road infrastructures prevent foreign investment in terms of economic performance and increase competition in the country. Currently, available approaches in managing road infrastructure projects have created separation of different phases of a project from each other in along the project lifecycle. This leads to lack of stakeholders' integration that in many cases it is considered as the main reason for project failure.

On the other hand, owners' main objective is project success. In this regard, integration of different phases of a project can be effective. This issue is significant when it comes to the maintenance phase of road projects that takes into account a large portion of costs. In this study, by using literature review, the necessity of integrating the maintenance stage with the initial stages of the project has been addressed. The results of this study show the significance of presence of the maintenance stakeholders in the earlier stages of the project. The results taken from this study provide a context that allows managers of future projects to feel the necessity of integrating different stages of a project and in this way, it reduces problems and duplications due to lack of coordination among different phases of a project.

*Keywords: road; infrastructure; integration; maintenance; stage*

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## 1. Introduction

All over the world, road construction network is considered as one of the main paths to growth. Given the budgets allocated to this type of infrastructure, its improvement becomes more significant (Ziyari and Karimi, 2008). In developing countries, considering the economic programs on one hand, and problems of the infrastructure projects on the other hand, conducting such projects needs a lot of money. On one hand, given the time of construction and operation- which is usually delayed- and basic challenges in them, these amounts are higher than the determined limit. Therefore, it is necessary to pay more attention to them (Taleghani, 2009).

Since roads are among the most important public assets and communication tools among users, using an appropriate planning and consequently, timely maintenance will help maintaining this national capital (Burningham and Stankevich, 2005). However, this issue increases significantly in developing countries, because it results in economic growth, poverty reduction, employment, and providing social services (Levik, 2001). In this way, effective

maintenance is considered as the required measures to guarantee large investments in this section (Ministry Of Local Government & Provincial Councils,2008); because the constructed roads will be destroyed by atmospheric factors and exploitation over time, and their initial value will be reduced (Tabatabaei and Rahman, 2009). In project management, the concept of “integration” is considered as “sharing information among the individuals involved in the project or combining information sources in separate systems (O'Connor and Yan, 2004). Integration is defined as “bringing together or combining a number of different items with each other, such that they can act as an effective and coordinated unit”. Today, this concept is becoming more complex, due to combining different needs of users. In this study, the researchers examines challenges due to lack of integration of different phases of the project, as well as the necessity of unifying knowledge and people in different stages of the project, to reduce duplications and costs. In the next section, the concepts addressed in this article are presented.

## **2. Literature Review**

So far many studies have been conducted on the challenges associated with the operation and maintenance phase, in which the integrity of the initial and final phases of the project is very significant to reduce the problems. Although much emphasis has been placed on this issue, still there are some projects suffered from lack of optimal collaboration in a project. Thus it is required to study the significance of the studied project (road construction) and finally the benefits of integrating the individuals of different stages in order to have a successful project in terms of time, costs, and the scope of these challenges. In the following we will discuss the related concepts.

### *2.1 Road Construction Projects*

In order to promote the economic and social development of a country, there is always a significant need to develop infrastructure installations (Ziayari and Karimi, 2008). Considering the number and significance of road construction projects, which are among the infrastructure projects, and their role in the economic growth of any country, it is necessary to pay special attention to these projects. In Iran, like other countries, roads are among the most significant infrastructures for transportation (Taleghani,2009). Looking at the budget law, it can be seen that, each year a large amount of government investment in the civil projects is devoted to transportation projects, which this amount is about 20 to 30 percent of the share of construction infrastructures (Budget Law, 2007). According to the above mentioned material, the reason behind why maintenance of roads is so significant is clear. Building new roads require huge investments, and without appropriate maintenance, they will be destroyed rapidly. In this case, if no measure is taken to maintain roads, their lifespan will be reduced from several decades to several years. This issue, in addition to increase maintenance costs, has a negative impact on the economy and road users (Levik, 2001).

### *Operation and Maintenance Challenges*

The ability to maintain or ease is called maintenance (Blanchard et al,1995). Costs of the maintenance stage include 50 to 80 percent of total costs of project lifecycle, which these costs

are so significant in the infrastructure projects. There is also lack of a study to integrate all phases of the project life cycle and the cost of duplications (Lewis et al, 2010;). However, appropriate maintenance of infrastructures leads to lengthen their life (Blanchard et al, 1995; Kordestani et al, 2016a). By entering the maintenance and operation stages in the initial stages of the project (design and implementation), it is possible to increase the attention of the project owners to the maintenance stage and avoid many possible problems. Moreover, it leads to poor reliability which is due to lack of attention to the maintenance and operation phases during planning and design stages. Therefore, the maintenance process should be integrated in the implementation stage to reduce costs (Kordestani et al, 2018c).

Usually contractors in a construction project experience the same challenges that many studies confirm it. Failure to provide a transparent project plan, lack of the capital needed to improve the skills of human resources and proper utilization of communication and information tools, are some of the mentioned problems (Sawhney et al, 2014). Delay in projects is another significant challenge that is observed repeatedly. Lack of sufficient funds and materials on the project site, lack of proper management, late delivery of the required materials, lack of the required equipment and tools, lack of coordination among different units, failure to monitor the job, not predicting climate, and changes in rules and regulations are related to this challenge (Wa'el Alaghbari et al, 2007).

Lack of strong and regular communication among all individuals is another major challenge, because establishing continuous relations and cooperation increases the performance of the operation and maintenance stage significantly. This issue has not been addressed in traditional methods of project implementation (Alshehri et al, 2015).

Finally, failure to update the resulting data in the project is another challenge that results in lack of proper improvement of the project. Due to lack of updated information gathered in terms of the length of time spent since their collection date, many of this information cannot be used in future projects, and keeping and recording them based on traditional methods is no longer useful and efficient. Thus, using digital formats is considered that updating them is easier. This method will allow project practitioners to update data using existing software at the required time and benefit from their valuable services to improve the project. Moreover, in this way all project stakeholders will have access to data throughout the project (Volk, 2014; McArthur, 2015). In order to resolve these challenges, it is necessary that various stages of the project interact more closely with each other, so the next section will address this issue.

### *2.3 Integrating various stages of the project*

In practice, integration refers to all cooperation, methods, techniques, and attitudes, which allow free exchange of information among various stakeholders (Baiden and Price, 2011). Because of such complexities, integration is addressed by many studies. In a comprehensive study (Trigunarsyah and Skitmore, 2010), it is stated that to achieve actual and complete success, it is very important to integrate the ideas of various phases of the project to achieve all of the intended objectives, matching the project for the final use, and effective and efficient maintenance of project assets to postpone recycle and to repel them. According to the concept of integration in the project, it can be pointed out that it is necessary that all stages of the project

life cycle be in an effective communication with each other to achieve project objectives and success. Various studies have also proven the necessity of integration of post-operation stages with the initial stages of the project (Assaf et al, 1996; Kordestani et al, 2017; Jadidol Eslami et al, 2016). However, despite the necessity of this issue, many managers and main stakeholders of the infrastructure projects, particularly road construction projects (considering the significance of the maintenance stage in reducing problems and duplications) have not pay sufficient attention to it and are always faced with previous challenges in the maintenance stage. Finally, civil projects experience huge costs and irreparable losses that lead to losing national capital. Therefore, this article has intended to consider the necessity of integrating different parts of the projects in order to have an effective interaction. Next section interprets the methodology adopted for this study.

### **3. Research Methodology**

Evans (1995) noted that to select any research methodology before describing it, it is necessary to provide the evidence needed to prove the appropriateness of the method for that special research; because the research goal may not achieve the desired result in this way. Maybe the first and easiest way of data collection method, is studying documents. Usually, there are a number of documents and materials about research topics used in the research process. Studying documents is done to find the subject areas, issue significance, understanding keywords, and subject structure, finding new perspectives, access to previous studies, finding sources comparable with other studies, discovering significant variables related to the topic, and supporting study data (Ahmadi and Salehi, 2013). Moreover, it is used to create a strong database for utilizing in the next stages (Yin, 2003).

The applied research method for this research is investigating the challenges of the maintenance phase of infrastructure projects and their main causes. In addition, the necessity of integrating the initial and final stages of the project, including design, and maintenance stages has been considered. This study consists of three main steps: at first, the literature review was conducted with the aim of providing a comprehensive view of the existing issues and problems. In the next section, the main causes of these challenges are examined, in order to resolve and improve them through considering their origin. Finally, in the third step, the researcher has examined how the integrity of the mentioned stages can be efficient, to make the project more successful.

### **4. Results and Discussion**

So far many challenges of the operation and maintenance stage in infrastructure projects have been identified, that due to negligence and lack of knowledge in the previous stages of the project. Therefore, it is necessary to resolve these problems. One of the effective strategies in this regard is integration of different stages of the project from beginning to end (Kordestani et.al, 2018a). Because problems such as lack of effective interaction of stakeholders, design mistakes, lack of feedback and effective monitoring are all challenges that are seen in the various stages of the project. Table 1 at first investigates the significant challenges of the operation and maintenance stage, and then shows the main source of each of these challenges

in the project by examining different sources. Finally, considering the research goal, it states that integration is a solution for improving them.

Table 1. Comparing between O & M challenges with their main sources and integration

O & M challenges	Challenges sources	How integration can improve the challenges
High amount of O & M costs (Bilal et al, 2015)	Lack of paying attention to the presence of maintenance in the early stages (Koo, 2000) Poor design of roads (Lee,1987)	Utilizing the knowledge and experience of people at different stages of the project can lead to reduction of challenges and replication (Bianchi, 2013; Saghatforoush, 2012)
lack of a proper stakeholder relationship with the contractor for exploitation and maintenance (Peng et al, 2017)	Lack of common goals (Florence et al, 2014), Lack of the benefits of interconnectionn (Karim, 2010)	Use of different types of contracts to unite the benefits (Karim and Magnusson, 2008; Karim, 2010)
Traditional information exchange that prevents optimal collaboration (Volk et al, 2014)	Unwillingness to collaborate with others and share information (Cheon Peng & et al ‘2014; Nita Ali & et al, 2002; Thomas & et al, 2002)	Use of different types of contracts to unite the benefits (Karim and Magnusson, 2008; Karim, 2010)
The accumulation of a large amount of information during the operation and maintenance phase and the lack of optimal use of this information (Peng, 2017)	Lack of shared data base between different project stages (, 1999; O’Connor and Yan, 2004, Russell, 2000; Florence et al, 2014)	The use of digital databases that are continually updated to communicate effectively with each other (Chen and Chan, 2016)
Estimated cost of project maintenance based on previous years (Alshehri et al, 2015; Lam et al, 2007)	Lack of knowledge of people working at different stages of the project (Meng, 2013; Karim, 2010)	Creation of an organized system for consulting and knowledge sharing among people involved in the project (Karim, 2011)
Poor access to optimal maintenance (Saghatforoush, 2012)	Lack of knowledge of designers regarding issues related to operation and maintenance (Cheon Pneg & et al ‘2014; Meng, 2013)	Creation of an organized system for consulting and knowledge sharing among people involved in the project (Karim, 2011)
A lot of rework is done during operation and requires a lot of repairs (Assaf et al, 1996)	Not Understanding the issues of exploitation and maintenance and lack of knowledge (Cheon Peng & et al ‘2014; Meng, 2013)	Holding workshops and training sessions to enhance knowledge with all the project stakeholders (Ochieng and Price, 2010; Lai et al, 2010)
Neglect and lack of proper planning in project maintenance (Karim, 2011; Ceran and Newman, 1992)	Invalidity and Lack of knowledge of maintenance managers (Saghatforoush, 2012)	Holding workshops and training sessions to enhance knowledge with all the project stakeholders (Ochieng and Price, 2010; Lai et al, 2010)
Problems arose due to the poor design and design of roads(Lam et al, 2007; Chew, 2010)	Lack of databases for recording feedback and experiences from previous projects (Karim & Magnusson 2008; Ahmed Mohamed 2005)	Creating a system for collecting feedback and updating information (Meier and Russell, 2000)
Prioritize other stages of the project for the maintenance phase and as a result of budget cuts required (Karim, 2010; Meng, 2013)	lack of attention of the authorities to the maintenance issue in the final evaluation of the projects (Karim and Magnusson, 2008)	Increasing senior management awareness with the concept and benefits of maintenance capability (Meier and Russell, 2000)



Road construction projects, like other infrastructure projects, are complex, because they have various components in the construction process. These stages are related to building and/or reconstruction of new roads based on the needs of transportation, climate, materials, and topography. One of the important aspects of this category of projects, is considering maintenance activities and the possibility to implement them in future (Karim and Magnusson, 2008), which is ignored in many organizations (Karim, 2011; Ceran and Newman, 1992). The relationship between maintenance and the initial stages of the project, can be stated by a sentence that includes thinking among maintenance personnel. They believe that “designers and engineers hold implementation for one year; while people in the maintenance stage should live with it for 20 years” (Lin, 2005). This issue indicates the significance of paying attention to the maintenance activities of the projects.

Many evidences have shown the significance of decisions taken in the initial stages of the project for effective and efficient maintenance (Brochner, 2003; Nawi et al, 2014) and maintainability (Chew, 2010). As most of the projects are designed and implemented by designers without considering aspects of maintenance, it leads to many problems in the maintenance stage (Saghatforoush, 2014; Arditi and Nawakorawit, 1999). Studies conducted in English have shown that 58% of problems available in projects is due to design flaws (Seeley, 1986), and 90% of them is due to lack of using the knowledge of maintenance personnel (British Standards Institute, 1984). According to Arditi and Nawakorawit (1999), 50% of maintenance problems can be reduced and resolved in the design stage, due to high flexibility and low costs of changes (FitzGerald , 2001).

On the other hand, during construction phases, lack of attention to maintenance in the early stages (Ceran and Newman, 1992), separate measures of entities, and lack of communication among stakeholders of various sections of the project, is the main reason of challenges of the maintenance stage (Seeley, 1986; Arditi and Nawakorawit, 1999; Erdener, 2003; ). In order to ensure implementation of new projects and maintenance of existing roads, road construction organizations have to increase their productivity and to reduce costs (Prarche, 2007). However, one of the main problems in the road construction projects and other infrastructure projects is high costs of maintaining projects that compose a large portion of annual infrastructure costs (Karim, 2011) and ultimately, will increase the final costs of the project.

Moreover, given the initial phases of the project life cycle, maintenance operation has always been a concern for contractors, employers, and consultants of the infrastructure projects (Bianchi, 2013) and this brings about design and construction promotion (Chong and Low, 2006; Kooren, 1987). Correcting mistakes and working methods provides access to suitable maintenance activities (Aris, 2006), and promotes the best practice Arditi and Nawakorawit, 1999). The inclusion of lessons learned and experiences obtained from various stages of previous projects, particularly maintenance, is essential to reduce mistakes in the early stages of the project (Hassanain et al, 2014). Because designers often do not understand what wrong approaches and decisions have been taken that caused many problems in the post-operation phase (Chew et al, 2004; Arditi and Nawakorawit, 1999). According to Ramly (2006) and Meng (2013), design plays a key role in determining terms after construction and generally

maintenance challenges. Therefore, examining the feedback of the maintenance stage staff can indicate this group of mistakes [4].

Many studies have pointed out that imposed costs in the maintenance phase can be much more than sum of the design and implementation phases ((Hassanain et al, 2014). According to definition (PMI, 2008), uncertainty, risk, and the impact of stakeholders in the initial phases of the project is more than the final stages of the project; however, the cost of changes during these stages is very low. For this reason, Mosey (2009) believes that the greatest opportunities are created in the early stages of the project to improve overall productivity of the project, because most of decisions are taken in these stages and they have the highest impact on subsequent phases such as maintenance (Erdener, 2003). In order to meet the high demand of the private and public sectors, it is expected that many problems of the design and implementation stages of the projects, later in the maintenance stage result in higher costs. Under normal conditions, as soon as the project is completed, its erosion begins. Accordingly, it is required to maintain projects in favorable conditions. A large amount of resources dedicated to maintenance are designed and implemented to eliminate corrective measures or resolve deficiencies. In England, about 20% of the average annual costs of repairing buildings is due to solving problems. Reducing design and construction defects leads to reduced maintenance costs (Gibson, 1979). Finally, maintenance measures are done based of the request of employers by maintenance contractors. Therefore, evaluating the design and implementation stage is important to identify the defects and to minimize those (Tope, 2014).

On the other hand, as mentioned previously, high cost of the operation and maintenance stage is a very important challenge in road construction projects (Bilal et. al, 2015). This challenge can arise for various reasons that the most important of them is not paying attention to the problem of operation and maintenance in the early stages of the project, which causes many problems for the project. Moreover, not paying attention to the correct design of roads and their maintenance in future will indicate the significance of integration in different stages of the project (Koo, 2000; Lee, 1987). By integrating different stages of the project, we can observe the utilization of knowledge and experience of individuals from the initial stages of the project to the end. In this way, many problems will be reduced, because we can be aware of the difficulties in different stages of the project, and do effective measures to prevent them (Bianchi, 2013; Saghatforoush, 2012).

The use of contracts that can increase the relationship among project stakeholders, is one of the measures that will be associated with project integration. Individuals from different stages are more likely to concern their benefits rather than the success of the project (Florence et. al, 2014). This issue accompanied with lack of understanding the benefits of mutual communication with other people involved in the project (Karim, 2010) are the reasons led to the challenge of lack of proper communication of project stakeholders (Peng et.al, 2017).

The type of contracts used in road construction projects has separated the project phases, so that people were not able to timely exchange information in the project (Volk et. al, 2014). This challenge by itself can be due to people's unwillingness to cooperate with each other (Nita Ali et.al, 2002; Thomas et.al, 2002; Cheong Peng, 2014). By following the type of the contract used, which is the result of project integration, individuals' benefits can be depended on the

success of the project and other stakeholders, in order to share information in the best way (Karim and Magnusson, 2008; Karim, 2010). In the following, the establishment of a database \_which is one of the advantages of integrating various stages\_ is considered effective in reducing the challenge of stacking a large amount of information in the maintenance stage (Chen Chang, 2016). Lack of a base that individuals can share and record their information (Liu et. al, 2015; O'Connor and Miller, 1994; Meyer and Russell, 2000; Florence et. al, 2014) is the main source of stacking of a large amount of information (Peng, 2007). Duplications (Assaf et. al, 1996), and lack of a proper maintenance plan (Karim, 2011; Ceran and Newman, 1992) are due to lack of knowledge of individuals at the initial stages of the project about operation and maintenance and its significance, and also lack of competence and knowledge of the managers (Saghatfroush, 2012). This problem can be solved by holding workshops and training sessions that enhance knowledge of the stakeholders (Lai et.al, 2010).

Lack of proper access to different parts of the project and lack of care for future maintenance, make people not to consider these problems when designing. This issue can be raised due to lack of prior information to state challenges and problems, because designers repeat their mistakes unaware of their possible defects (Karim & Magnusson, 2008; Ahmed Mohamed, 2005). Therefore, the project should be integrated so that individuals can access project information and get feedback from previous collaborations in order to achieve improvement and progress (Meier & Russell, 2000). According to the above-mentioned issues, the need for project integration is even more important, because it can lead to a reduction in potential problems in the project and direct the project towards success.

## **5. Conclusion**

Examining the experiences and lessons learned of maintainability in the early stages can prevent many costly defects of maintenance (Moua and Russell, 2001). According to Karim (2011), lack of sufficient attention to the maintenance aspects and also lack of sufficient support of designers during the initial phases, are two important factors in rising the costs of the maintenance phase. The main factors that hinder taking into account maintenance in the initial stages of the project, are incorrect estimation of costs, shortage of time, and insufficient experience of road designers about maintenance issues. On the other hand, in the project conducted in (Kordestani et al, 2018a; Kordestani et al, 2017; Jadidol Eslami et al, 2016; Kordestani et al, 2018b), it was determined that many problems of the maintenance stage are due to lack of understanding the concept of maintenance in the road construction projects especially in developing countries by people involved in the initial stages of the project, which leads to taking incorrect decisions.

In the future studies, researchers can focus on the process of implementing integration in the road construction projects and localizing the experiences of other countries and successful projects in this field, and managers can utilize this knowledge in developing such processes in the projects to achieve more success and to maintain national capital. On the other hand, this study is focused on the road construction projects, which are heavy national projects, therefore it is important to examine this issue in the civil and infrastructure projects, in order to determine whether these projects face such problems and challenges or not.

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# Development Infrastructure Programs in Turbulent Environment

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## Abstract:

Analysis of existing models and methods of threat management development programs within such industry was performed. A three-level model of the high technology production within institutional, managerial and technical levels was also considered. Classification of threats in high-tech industries development programs was determined, based on their reaction - deviations (reactive) and resentment (proactive). An immune mechanism as a response to threats and challenges in the development programs was also considered. Key unit diagnostic mechanisms and critical threats, which belong to the field of Pareto, working out alternative scenarios for threat management, the formation of a full immune response to a threat to the region Pareto taking into account their mutual influence and realization of immune response in the form of high-tech industry development project were all considered in the article.

*Keywords: management mechanism; development programs; turbulent environment*

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## 1. Introduction

The rapid development of project and program management methodologies requires the creation of innovative models, methods and mechanisms based on the convergence of different subject field knowledge. Over billions of years, nature has created a variety of living organisms with unique survival mechanisms in a dynamic and sometimes aggressive environment. Some of such mechanisms are protective (immune) mechanisms, which develop a special reaction to the threats. The process of knowledge transfer from one domain to another was formed in the 1950s, within the similarity theory of mechanical, electrical and biological systems.

## 2. Analysis of recent achievements and publications

Let's consider the use of different methods of analysis of threats, including self-test, in the development of project-oriented systems.

Diagnostics in the context of life cycles analyses of products, technologies of production, management processes of operations, business development and implementation, is usually carried out in the framework of management system using the model of the project-oriented organization life cycle (Prigogine, 2009). When threats of an organization are analysed, whether this is done by personnel themselves, or using the help of specialized consultants, it determines the position of the organization in its development, its passed crisis points and its expected further development (Azarov, 2012). In the process of forming a development program for high-tech production, complementary chains of projects are formed based on certain horizons of vision. At each step of the process, there is a clarification of the project's vision and corresponding synchronization.



The use of diagnostic tools depends on the development strategies for the project-oriented organization and the state of the context. Thus, the strategy of a breakout in the development of new markets and the competitive edge is stipulated with the high level of innovation of influential competitor in the market segment of knowledge-intensive industries. Identification of positive reaction in management processes is one of the elements of the concept of growth cycle and allows to look at the balance of efforts and dynamics of competition in current market conditions, to identify and classify growth accelerators - factors that ensure sustainable development of high-tech industry, and to provide managers with a new tool for modelling corporate strategy (Kerzner, 1998).

When Analysing threats, an organization is considered at the following levels:

*Institutional level*, which is the top management, which forms the purpose of high-tech enterprise, planning strategy, business implementation and development of an organization. This level of management is carried out by the top managers or top executives. The competence level of these managers is an important decision making for the company as a whole. Top managers are mainly involved in the development of perspective plans and long-term programs focused on company adaptation to changes in the external environment as well as the definition of applied methods, tools, technologies and systems to improve performance of organization's business and productivity of the enterprise' employees as a whole.

*Managerial level*, which is the middle management, intermediate between strategic management and routine for implementation of the current tasks of the enterprise. The competence level of this management is determined by decision-making within the subdivisions of the enterprise and the realization of its tactical objectives. Middle managers are typically in charge of subdivisions and/or departments within organizations. These managers are mainly engaged in the management and coordination of high-tech enterprises. They make decisions on various forms of activities and efforts of various departments.

*The technical level* is lower management, which is directly involved in supervising production staff. Managers at his level generally supervise the implementation of production objectives, deal with daily operations and the actions needed to ensure efficient work without disruption in business processes.

One of the key tools for threat analysis in the development is *structuring*.

The following examples of project structures may be considered:

- tree of objectives;
- tree of tasks (work);
- tree of products (results);
- problem tree;
- decision tree;
- work breakdown structure;
- the organizational structure of the project;
- and so on.

The structures are developed on the basis of analyses of systems and models. One of the main methods of structural analysis is decomposition. Decomposition is a conditional technique that allows to introduce a system in a useful form and assess its complexity. As a result of decomposition, individual structural elements of a system and the relations between them are categorized based on their characteristics. Decomposition is a way of avoiding threats in high-tech industry through the development of an understanding of a system. The depth of decomposition is determined by the order and complexity of a system, as well as the objectives of the task in hand.

The use of structural models leads to a requirement for their classification. Classification of objects represents their conditional grouping by given characteristics in accordance with a certain purpose. For various purposes, the same organizational threats may be classified differently. The classification is not an end in itself, it is imposed by the theory and practice needs. Effective classification of models provides convenience when choosing methods of modeling threats and achieving desired results.

Initialization conditions of high-tech industries development projects depend on the sources of its creation. As any living organisms projects are born, realized ("live") and completed ("die") according to certain laws. It should be noted that the projects are not "born" accidentally. Every "new-born" project has its own story, "background" and "genetics".

The use of biological analogies, as suggested above, in project management mechanisms allows to use and transfer knowledge and experience from biological science. Development of biological science, although it is a descriptive science, offers an excellent opportunity to detail the fields of project management methodologies that are not yet considered.

The analogy allows the use of relative structure and configuration of objects in one subject field to create "skeletons" for a detailed elaboration of structural features of objects in the field being studied. As an example of these biological concepts of "genetics" and "immune mechanism" are being used in the field of project management.

The purpose of the "genetics" project as science was to identify the general laws of the transfer of knowledge from one project to another. For this, specialists had a task of identifying the mechanisms underlying the laws of genetics and associating them with project structure elements. In the process, the question came up of how and in which manner the project and its "genetic information" may turn into characteristics of the developing project. "Genetic information" of a project covers the whole range of features and characteristics that the project has during its lifecycle, from the moment of its "birth" until completion. Each project exists in its own environment and the formation of its structural features occurs in well-defined conditions, with each structure depends not only on "hereditary background", but also on the conditions in which the structure is implemented and developed on the basis of the "model of the environment."

The process of creating a genetic model can be considered.

During its growth, each organization is faced with certain difficulties, challenges, and threats. At each stage of organizational development, these can be divided into two categories (Adezis, 2009):

- growth threats, i.e. problems caused by the immaturity of an organization, which are difficult to avoid (like children's infectious diseases);
- organizational threats (internal and external), or difficulties which may relate to certain phases of the organization's development.

If correct strategy and tactics of development are used, the high-tech production can achieve prosperity and, in principle, remain in this state for a long time, contrary to the analogy between the development of a business organization and a living organism.

The modern practice of system creation and development in project management shows that each methodology is formed from scratch. As such the same mistakes can be repeated many times. Project management methodology is regarded as a basic tool for development, control of organizational “disease” and formation of its competitive advantage (Bushuyev, 2012). It is argued that the creation of a knowledge management system of project portfolios and program management methodologies is a promising research trend. The use of knowledge of protective (immune) mechanisms in the living world in the construction of methodologies, allows the use of the immune system structure, as a knowledge-carrier of project management methodologies of the high-tech industry. This structure allows to divide the knowledge of methodologies into classes and to use that knowledge in creating effective project management methodologies that are adapted to the specifics of the enterprise and classes of projects and programs (Azarov, 2012).

### **3. The purpose of the study and problem formulation.**

The aim of the article is to build a mechanism for the development of programs for threat management in a turbulent environment.

1. To analyze existing mechanisms of threat diagnostics in programs of development
2. To classify threats (external - internal; by zones of turbulence with reference to the book, by expected losses in the system during program implementation.)
3. To build a conceptual model which will include mechanisms for diagnosis of threat-response mechanisms in the development programs of high technology industries.
4. To create a case study through development programs of high-technology industry in a turbulent environment.

The main hypothesis of the study is that the key factor of success of high technology industry development programs is the development and use of diagnostic and threats management mechanisms.

#### 4. Conceptual model of analyses programs threats

The following structure of the threat classification is used, by classification features (Yaroshenko, 2012):

- those concerning the organization - external, internal threats.
- those concerning the environment - by turbulence zones: green, yellow, red, brown and black.
- those concerning expected losses in the system during program implementation: insignificant, essential, destructive for the organization.

The conceptual model for analyses of program threats defined during the project life cycle. Basic principles of the conceptual model are:

- the model must take into account uncertainty, risks and threats;
- the model must take into account interactions between uncertainty, risks, and threats (fig. 1).

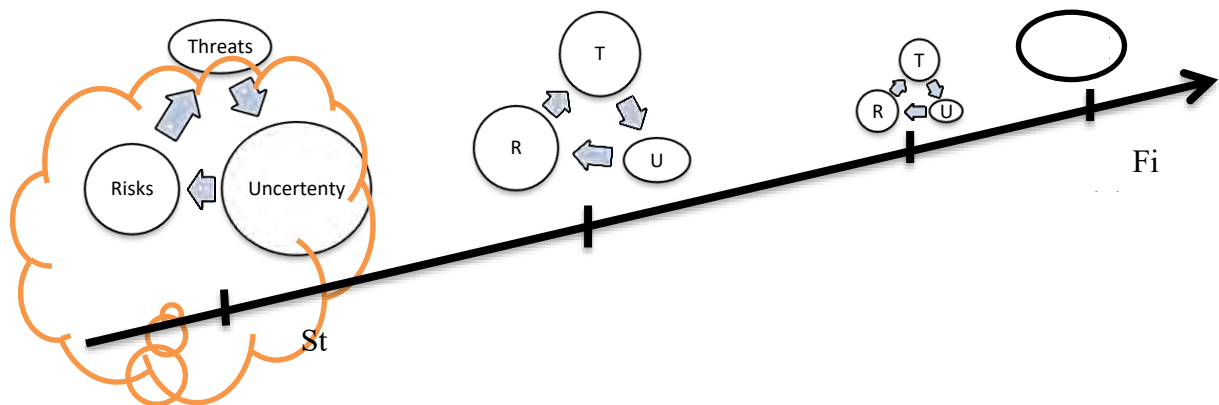


Fig. 1. The conceptual model for analyses of program threats (our own resource)

According to the proposed concept at the start of the process, there is big uncertainty, small risks and threats with a vision 'in a cloud'. In the next phase, uncertainty becomes smaller while risks and threats become realistic. At the end of the program, there is a transformation from risks and threats of the program to products while uncertainty becomes zero.

#### 5. Management of threats in developed programs

##### 5.1. Case study 1. Threats to industrial high technology enterprises

Currently, there is not much literature dedicated to the problems of threats to industrial high technology companies, in spite of the fact that they are the riskiest businesses. For the efficient organization of risk management at industrial enterprises, it is necessary to develop the classification of threats.

Analyses of the literature showed a lack of a clear and structured integrated classification of threats in an Industrial High Technology Enterprise (IHTE). Therefore, the classification of threats in accordance with the functional components of IHTE was proposed. With this in mind,

an inquiry form, which included the main threats of IHTE was drawn up and an expert survey was performed.

The views of experts in the field from the leading industrial enterprises were gathered.

Analysis of the proposed threats classification of IHTE was carried out using the weighting coefficients obtained by the expert methods of estimation. The experts were asked to rank the threats to IHTE in order of importance. In this case, 10 experts were interviewed according to each threat to each of the IHTE functional components.

A criterion of estimation was the significance (weighting) of risk, i.e. which of the listed threats to IHTE were considered by the experts to be the most and least important for the stable operation of the company

The first rank was assigned to the most significant threats to the IHTE.

As rank increased the significance of threat decreased. The last rank (depending on the number of threats in the functional component of IHTE) was assigned to threats which were considered to be of least importance for an enterprise.

After processing the inquiry form for each indicator, the rank total ( $R_i$ ) was calculated taking into account the opinions of all the experts:

$$R_i = \sum_{j=1}^N r_{ij} \quad (1)$$

where  $r_{ij}$  is the  $i$ -th threat rank assigned by the  $j$ -th expert.

To move from the rank estimates  $r_1, r_2 \dots r_n$  to the weight coefficients ( $a_i$ ) Fishburn's formula was used, as follows:

$$a_i = \frac{2(n - r_i + 1)}{n(n + 1)}, \quad (2)$$

where  $n$  is the number of estimated objects (?).

This formula was used because it assumes linear weight decrease from rank to rank.

Table 1 shows the classification of IHTE threats obtained as a result of the expert survey and calculated weighting coefficients.

An important point of the expert procedures is the evaluation of experts' action concordance and reliability of expert scores.

To determine this, the coefficient of concordance was used. The value of this coefficient gave an indication of the degree of concordance of expert opinion and, consequently, of the reliability of their scores.

Table 1. Results of the expert survey (our own resource)

Functional component of IHTE	Classification of threats to IHTE	$R_i$	rank	$a_i$
1. Finance	Objective:			
	1. Circumstances outside one's control or similar to them in themselves or in sources of appearance. (political, of macroeconomic nature, economic, national, religious issues)	34	3	0,2
	Subjective:			
	2. Inefficient budgeting of all aspects of the activity	20	2	0,3
2. Production	3. Unqualified enterprise asset management	10	1	0,4
	1. Non-conforming production (non-compliance with requirement of time, unable to manufacture competitive products)	14	1	0,4
	2. Non-conforming supplier of components, raw materials, expendable materials, etc.	16	2	0,3
	3. Insufficient awareness of innovative technologies	36	4	0,1
3. Marketing	4. Inappropriate infrastructure	34	3	0,2
	1. Limited market for the final product	25	2	0,24
	2. Non-compliance of the products with market requirements	13	1	0,29
	3. Risks related to market development	39	4	0,14
	4. Insufficient awareness about changes in the market	53	6	0,05
	5. Non-professional advertising	45	5	0,1
	6. Risks related to market conditions (exchange rate risks, price variance risks, competitive expansion risks)	35	3	0,19

From the above, the coefficient of concordance ( $W$ ) is determined using the following formula (3):

$$W = \frac{12 \sum_{i=1}^n \left( \sum_{j=1}^N r_{ij} - \frac{N(n+1)^2}{2} \right)}{N^2(n^3 - n) - N \sum_{j=1}^N L_j}, \quad (3)$$

where  $N$  is the number of experts;

$r_{ij}$  is the rank of the  $i$ -th threat assigned by the  $j$ -th expert;

$L_j$  is an indicator of related ranks of the  $j$ -th expert.

$L_j$  value is determined by the following formula:

$$L_j = \sum_{v=1}^{k_j} (k_{jv}^3 - k_{jv}), \quad (4)$$

where  $k_{jv}$  is the number of the same ranks in  $v$  group of the  $j$ -th expert;

$k_j$  is the number of groups of indicators with the same ranks of the  $j$ -th expert.

The coefficient of concordance  $W$  can vary between 0 (where there is complete lack of concordance) and 1 (in the case of agreement of the ranking results of all experts). The degree of concordance of expert evidence is considered acceptable if  $W \geq 0,7$ .

Table 2. The results of experts' opinions concordance (our own resource)

Functional components of IHTE	Coefficient of concordance
1. Finance	0,9
2. Production	0,81
3. Marketing	0,59

Table 3 below shows the most significant threats to IHTE, which were found according to the experts as a result of the calculations

Table 3. Most significant threats to IHTE

The functional component of IHTE	Threats names of IHTE
1. Finance	Inefficient enterprise asset management
2. Production	Imperfect production (noncompliance with the requirement of time, unable to produce competitive products)
3. Marketing	Noncompliance of the products with market requirements

Ensuring compliance of each functional component of IHTE with requirements may be achieved by carrying out an individual set of measures for each component.

It was noted that all of the functional components of IHTE were closely interrelated and hence it would not be possible to achieve stability of an enterprise through adjusting just one of these components, without bringing the others to the required level

On the basis of the expert survey mentioned above, classification of industrial enterprise threats was proposed for practical use, allowing develop directions for the preventive measures to ensure the stability of the industrial enterprise.

### *5.2. Case Study 2. Assessing and developing organizational competence in PrOJECTS with High risks and threats as seen at Chernobyl Nuclear Power Plant (ChNPP)*

In the 1980s, ChNPP was one of the most powerful nuclear power plants in the USSR. According to the strategic development plans of power industry of the Soviet Union, the ChNPP had to become the largest nuclear power plant in the world, consisting of six power units with an electric power of 1000 MWt each (corresponding to 3200 MWt of thermal power each respectively).

However, the devastating explosion of the fourth power unit of ChNPP on 26 April 1986 changed everything. The accident caused emission of a huge amount of radioactive materials into the environment. About 600.000 people participated in the elimination of consequences of the largest accident in the history of nuclear power, 200.000 people were evacuated and moved out of the area, and the health of 1.7 million people was undermined. The death toll related to the Chernobyl accident, including those died from cancer years later, according to official data sources was estimated at 125.000 people.

In 1986 in just six months, in difficult radio-active conditions, scientists and experts of the former Soviet Union designed and constructed a protective cover for the damaged reactor, which was named the "Shelter", and was later renamed to "Sarcophagus". Implementation of

design decisions during the construction of "Shelter" object in a difficult radiation situation demanded implementation of a range of organizational and technical actions to ensure radiation protection of the personnel. Practical implementation of the fundamental principles of radiation safety while carrying out dangerous works was reliably supported by the strictest discipline and quickly developed and put into practice instructions and regulations of performance of all radiation-hazardous works.

In 1994 political leaders of the world, represented by the G7 and the European Union requested that Ukraine stops operations of the remaining nuclear power stations of ChNPP. In 1995, Ukraine signed a Memorandum of Understanding to stop power units of the ChNPP which eventually happened in 2000. A year later, the State Specialized Enterprise Chernobyl NPP (SSE ChNPP) was formed by the Ukrainian Government to decommission the existing power units and to transform the "Sarcophagus" into an ecologically safe system.

A complex three-stage program was started. In Stage 1 the objective was to stabilize the existing "Shelter" by increasing reliability and durability of the old structures and systems. Stage 2 was aimed at creating additional protective barriers, firstly through creating new safe confinement providing necessary conditions (e.g. to ensure the safety of the personnel, the local population, and environment), preparatory technical work and the infrastructure for stage 3. This included erection of the "New Safety Confinement (NSC)", which was an arched construction with a width of 257.4 meters, a height of 108.4 meters and the length of 150 meters. The NSC was designed for 100 years of operation to give the chance to carry out extraction of fuel-bearing materials and their conditioning for the subsequent safe storage (Fig. 2).



Fig. 2. NSC after the second lift of eastern section in 2013

After the erection of the NSC in 2015, stage 3 would start and is planned to be carried out by 2023. It is aimed at the extraction of fuel-bearing materials and long existing radioactive waste, their conditioning, and burial in radioactive waste storages in accordance with existing standards, removal from the operation of the "Shelter" and dismantling of unstable structures of the "Sarcophagus"

Financing of works on the international project (the plan of implementation of measures on "Shelter" object) is carried out at the expense of the donor countries of the international Chernobyl Fund "Shelter" (ChFS). The European Bank of Reconstruction and Development (ERDB) provided help to the government of Ukraine in organizing the international conference



on fund-raising to cover the missing financing of the program. As a whole, the construction of the NSC arch is expected to cost in excess of 1 billion Euros.

One of the challenges for the ChNPP was the lack of personnel with sufficient experience in implementing such a complex program and with coordination of all related projects. A Project Management Unit (PMU) was formed to establish standards for project and program management in accordance with the internationally acknowledged standards (Bushuyev, 2014). The PMU of ChNPP worked closely together with Ukrainian Project Management Association (UPMA) and Kyiv National University of Construction and Architecture to develop the standards and the competence of personnel involved in the program and projects with application of IPMA OCB model (IPMA OCB, 2013).

## 6. Conclusions

From the analyses presented the following can be presented:

- a systemic approach to the definition of threats in high technology production project management allows to make conclusions on feasibility and relevance of using "immune mechanisms" in making decisions;
- formation of immune mechanisms within project management methodologies based on the analogy approaches can only occur after the steps of convergence and integration of threats and challenges in development programs of high technology enterprises.
- use of methods for determining the degree of similarity between systems allows to choose a model of immune mechanism, and justify the relevance and feasibility of using analogy approaches for the formation of effective project management methodologies.

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# Exploring Critical Success Factors for Managing Sustainability in Construction Projects

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## **Abstract:**

The modern construction industry has met several barriers on its way to sustainability, including issues of financial and risk disincentive or the lack of clients' awareness. In order to overcome these, the project management team needs to have clear guidance on how to manage sustainability in building projects, which does not exist at the moment in the current project management standards and tools. However, to be able to develop project management guidance, it is essential to first understand the critical success factors (CSFs) for sustainability management. For this purpose, an extensive literature review carried out on the topics related project management led to the identification of 30 potential factors contributing to the achievement of sustainability in construction projects, which were then categorised under five groups of factors. In order to understand the relationships between these groups of factors in real projects, a structured questionnaire containing these CSFs was carried out with the participation of experienced professionals in the UK, and 144 valid responses were retrieved. Structural equation modelling technique was used to analyse data collected. The research finding shows that sustainability assessment and stakeholder management has positive and significant impacts on the achievement of sustainable project success. The results also identified inter-relationships among the five groups of factors in a way that sustainability goals are highly required to give project team sufficient power and allow them to use proper abilities in managing stakeholder, in planning and assessment of project toward sustainability; and finally, sustainability planning is a supportive preparation for the sustainability assessment of buildings.

*Keywords: sustainability; project management; construction buildings; stakeholder management; project success*

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## **1. Introduction**

Recently, the construction industry has been challenged with higher requirements for sustainable buildings with the focal point moving to zero carbon and net-zero buildings. Several tools and techniques have been developed to enable sustainability in construction buildings. The most straightforward techniques are in the form of a sustainability checklist, such as ones demonstrated by RIBA (2013) or Silvius (2010). More comprehensively, a wide range of green building rating systems (i.e. BREEAM, LEEDS or CASBEE) targets the assessment and assurance of a building with pre-identified features of sustainability. In order to evaluate all economic, social and environmental impacts in one single method, project managers can use techniques such as Life-Cycle-Costing, Life-Cycle-Assessment (LCA) or the combination of them, Life-Cycle-Sustainability-Assessment (Klöpffer, 2003; Schau *et al.*, 2011).

The existing tools consider sustainability features as requirements to be fulfilled through a quality management approach or quality assessment standards (Sánchez, 2014). The bare application of such tools or techniques is not sufficient to do the "right things right" (McKinlay, 2008). These tools mainly focus on defining and measuring sustainable features of final products, but they are less clear in guiding project management practice to initiate and to deliver sustainable projects.

Although the lifecycle-based techniques increased the focus on the cost of sustainability for the whole lifecycle, the current project management approach still heavily concentrates the effort on delivering the project within the time, cost and quality expectations up until the building completion rather than the whole lifecycle. This short-term financial concern is mostly aligned with the interests of project investors who do not want to add more complexity to the constraints of time/budget/scope (Silvius and Brink, 2014). The need for a change in project management practice for integration of sustainability has also been highlighted by other authors, including Carvalho & Junior (2015) and Marcelino-Sádaba, González-Jaen, & Pérez-Ezcurdia (2015).

However, there is still no clear method of how project management can support sustainability achievement of construction projects (Hwang and Tan, 2012). Project management standards like PMI, IPMA, AIPM, APM, PRINCE2 or ENAA pay very limited attention to the issues of sustainability (Martens and Carvalho, 2016). This dominant approach guided by these standards might be the main reason that made the difference between concepts of current project management and sustainability, which shown by Silvius & Brink (2014).

A potential solution to integrate sustainability into project management, therefore, requires a change in project management (Carvalho & Junior, 2015; Marcelino-Sádaba, González-Jaen, & Pérez-Ezcurdia, 2015). McKinlay (2008) criticised that the bare application of such tools or techniques summarised above might not be sufficient to do the "right things right". Silvius & Schipper (2014) suggested three specific changes are necessary to move towards sustainable project management: a shift in project scope; a shift in paradigm; and a shift in the project manager's mind. Khalfan (2006) developed a sustainability management model, which is integrated into the generic design and construction process protocol. However, the model bears no attention to human-related factors, which has been recently recognized as a significant barrier to sustainable projects. These factors are referred as the lack of stakeholders' awareness and engagement (Persson and Gronkvist, 2014); limited knowledge and skills of employees, lack of collaborative working, resistance to change, and inadequate competencies of project team (Heffernan *et al.*, 2015); and failure in information transparency (Persson and Gronkvist, 2014). Likewise, Tharp (2013) suggested that the incorporation of sustainability into project management practices should consider stakeholder management, human resource management, and communication management.

Recognizing the gap in knowledge, this study is in line with the efforts of changing project management towards sustainability. It is aimed at developing an integrated explanatory model for understanding relationships between project management factors and sustainable project success. This model is then empirically tested using a structural equation modelling (SEM) approach.

## *Sustainable Project Management (SPM)*

Modelling for sustainable project management in this study relies on project-management related success factors for achieving sustainability in building projects. After an exhaustive review, 30 success factors were identified and categorised into five groups of factors. These five groups are then accepted as five key components of the sustainable project management, including (1) project team enhancement, (2) stakeholder management, (3) sustainable goal setup, (4) sustainability planning, and (5) sustainability assessment (See Table 1).

### *Project team enhancement*

The project team is defined as all internal employees, including not only project managers and management team, but also designers, main and sub-contractors, and other key ones who work in the project and contribute to the success of the project. Recent research highlighted the role of this human resource, especially the central position of project managers, as a critical part in sustainable projects (Goedknecht, 2012; Hwang and Ng, 2013; Silvius and Brink, 2014).

### *Stakeholder management*

Stakeholder in construction projects has been recognized as a vital role supports the sustainability achievement in recent researches (Gareis, 2013; Abuzeinab and Arif, 2014). Because sustainability requires paying more attention to the full life-cycle perspective, then it is necessary to consider long-term values by stakeholders (Vink *et al.*, 2010) as well to get their engagement from early stages (Robichaud and Anantatmula, 2011; Kalutara *et al.*, 2017).

### *Sustainability goal setup*

As project is recommended to shift from managing time, budget and quality to managing sustainability impacts (Silvius and Schipper, 2014), then considering sustainability achievement as a project goal has a critical meaning (Robichaud and Anantatmula, 2011; Gareis, 2013) because it is 'ultimately necessary to give the various players a direction for their activities' (Kibert, 2013). RIBA (2013) highly recommend having a clear and official declaration of the owner regarding sustainable goals to all stakeholders.

### *Sustainability planning*

A sustainability management plan is critical to navigate further actions of managing sustainability-related activities in the project. To develop the plan, project managers are recommended to start with the identification and assessment of sustainability-related risks and issues (Gudienė *et al.*, 2014; Khalfan, 2006; Perrott, 2015; Pojasek, 2012), then necessary actions might be proposed and prioritized (Verboven & Vanherck, 2015, 2016) to face risks and issues identified. Carboni (2013), FIDIC (2013), and Silvius (2015) proposed three templates for the project sustainability management plan, including the four main parts: (1) introduction of the project, organisational context and objectives; (2) preliminary analysis of project impacts, risks and opportunities; (3) metrics for controlling sustainability; and (4) sustainability governance.

## Sustainability assessment

Sustainability assessment plays a significant role in measuring and assuring sustainability in the built environment. It should be followed from the start to the end of the project. In the design stage, it is necessary to check standardised requirements and regulations issued by local governments about sustainable development, then the assessment of environmental, social and economic impacts of the project should be carefully considered (Anthony R. Lapinski, Horman and Riley, 2006; Curran, 2012). Project team could take advantage from a large number of green building rating system (like BREEAM, LEED, or Green Star), and pre-assessment techniques like life-cycle costing (LCC) and life-cycle assessment (LCA). During the construction, the project team needs to monitor and measure the performance and progress of sustainability achievement in the project (FIDIC, 2004; Perrott, 2015). When construction finishes, building commissioning is highlighted as a systematic process for quality control to ensure the owner's goal for a green building (Stum, 2000; Tseng, 2005). In the operation stage, post-occupancy evaluation (POE) can help to diagnose operational problems and then it may allow improvement of user's satisfaction and performance of the building.

Table 22: Indicators for Sustainable Project Management

Label	Success factors	Contributors
<i>ENHA</i>	<i>Enhancement of project team</i>	
Enha_1	Responsibility and power for project team members to do their jobs	Low, Gao & Tay (2014)
Enha_2	Innovative solutions from project team members proposed (and discussed)	Shen, Tang et al. (2017), Sim & Putuhena (2015), Vink et al. (2010),
Enha_3	Workers' health, safety and working conditions in a construction site	Gudiene et al. (2014), Zou & Moon (2014), Glavinich (2008),
Enha_4	Project team's skills and knowledge in executing project activities	Banihashemi et al. (2017), Shen, Tang et al. (2017), Saleh, Mohammed & Abdullah (2015), Gudiene et al. (2014), Low, Gao & Tay (2014)
Enha_5	Project managers' competences and experience about sustainability in construction projects	Shen, Tang et al. (2017), Banihashemi et al. (2017), Saleh, Mohammed & Abdullah (2015), Gudiene et al. (2014), Low, Gao & Tay (2014), Volker (2011)
Enha_6	Collaboration, communication and information transparency among project team members	Wang N. et al. (2015)
Enha_7	Special advisors/champions involvement in a project to support for achieving sustainability targets/goals	Thomson et al. (2011)
Enha_8	Project team members are motivated towards sustainability at the beginning of the project	Shen, Tang et al. (2017), Gudiene et al. (2014)
Enha_9	The continuous learning process is implemented among the project team	Low, Gao & Tay (2014), FIDIC (2004)
<i>STAK</i>	<i>Stakeholder management</i>	
Stak_1	Long-term value creation by all stakeholders is fully considered	Vink et al. (2010),
Stak_2	Key stakeholders' vision, strategies & objectives are determined to align them with project goals	Verboven & Vanherck (2015), FIDIC (2004)
Stak_3	Engagement of internal and external stakeholder to project activities	Marcelino-Sádaba, González-Jaen & Pérez-Ezcurdia (2015)
Stak_4	Effective communication with clients and other stakeholders	Shen, Tang et al. (2017), Wang N. et al. (2015), Saleh, Mohammed & Abdullah (2015), Gudiene

		et al. (2014), Low, Gao & Tay (2014), Volker (2011)
Stak_5	Stakeholders (including users, operators, client, sub-contractor...) are involved in the early stages of projects	Kalutara et al. (2017), Shen, Tang et al. (2017), Robichaud & Anantatmula (2011)
<hr/>		
<i>GOAL</i>	<i>Sustainable goals setup</i>	
Goal_1	Promotion of stakeholders' awareness, knowledge and commitment to invest in sustainability	Banihashemi et al. (2017), Saleh, Mohammed & Abdullah (2015), Swarup, Korkmaz & Riley. (2011), Vink et al. (2010)
Goal_2	A sustainability ambition is created among project team members at the beginning of the project	Silvius, Neuvonen & Earola (2017), Volker (2011)
Goal_3	A declaration of the owner regarding sustainability goals is announced to all relevant stakeholders	RIBA (2013)
Goal_4	A sustainability mission statement with tangible objectives is fully considered in the project brief or project plan	Banihashemi et al. (2017), Wang N. et al. (2015), Vink et al. (2010), Khalfan (2006), FIDIC (2004)
<hr/>		
<i>PLAN</i>	<i>Sustainability planning</i>	
Plan_1	Identification, assessment, prioritisation, and planning of sustainability-related risks and issues	Banihashemi et al. (2017), Wang N. et al. (2015), Gudiene et al. (2014), Saleh, Mohammed & Abdullah (2015), Khalfan (2006), FIDIC (2004)
Plan_2	Considering sustainability achievement when selecting the project delivery method	Kibert (2013), Swarup, Korkmaz & Riley. (2011)
Plan_3	Waste reduction, reuse and recycle in the project is considered in the project plan	Banihashemi et al. (2017), Kalutara et al. (2017), Zaini & Endut (2014), Zou & Moon (2014), RIBA (2013)
Plan_4	Natural environment conservation is considered in the project plan	Banihashemi et al. (2017), Kalutara et al. (2017), Wang N. et al. (2015), Al-Yami & Price (2006),
Plan_5	Efficient and environmental-friendly technologies and materials are used	Kalutara et al. (2017), Gudiene et al. (2014), Kibert (2013), Spiegel & Meadows (2012), Glavinich (2008),
Plan_6	Proposing and prioritising sustainability-related activities	Verboven & Vanherck (2015)
<hr/>		
<i>ASSE</i>	<i>Sustainable assessment</i>	
Asse_1	Green building or energy performance certificates targeted	Gudiene et al. (2014), Vink et al. (2010)
Asse_2	Project management team considered sustainability-related standards to apply in the project	Zaini & Endut (2014)
Asse_3	The project management team had sufficient understanding of regulations and legislative forces about sustainable development	Kalutara et al. (2017), Gudiene et al. (2014), FIDIC (2004)
Asse_4	Environmental, economic and social impacts assessment in design and early stages of the project	Curran (2012), Lapinski, Horman & Riley. (2006)
Asse_5	Sustainability performance/progress is monitored and measured the project	Banihashemi et al. (2017), Perrott (2015), FIDIC (2004)
Asse_6	Post-construction evaluations (Building commission and post-occupancy evaluation) are carried out	Saleh, Mohammed & Abdullah (2015), Robichaud & Anantatmula (2011), Thomson et al. (2011), Tseng (2005), Stum (2000)

### *Conceptual model and research hypotheses*

After SPM and SPS were conceptualised, the study came up with questions related to the inter-relationships among the five key components of sustainable project management as well as a hypothesised question about the impact of these components to Sustainable Project Success

(SPS). The authors view the sustainable success of building projects as the achievement of traditional project success (i.e. project performance and stakeholder satisfaction) and the targets of economic, environmental and social sustainability under the triple-bottom-line model.

Five hypotheses (and 15 sub-hypotheses) were developed on the inter-relationships among the five key components of SPM and the supportive relationship of the five key components of SPM to the achievement of SPS.

- Hypothesis 1: The definition of sustainability goals supports for the enhancement of project team toward sustainability (h1a), the planning for sustainability (h1b), the assessment of sustainability (h1c) and the implementation of stakeholder management (h1d);
- Hypothesis 2: The enhancement of the project team toward sustainability supports the planning for sustainability (h2a), the assessment of sustainability (h2b) and the implementation of stakeholder management (h2c);
- Hypothesis 3: The planning for sustainability supports the assessment of sustainability (h3a) and the implementation of stakeholder management (h3c);
- Hypothesis 4: The assessment of sustainability supports the implementation of stakeholder management (h4);
- Hypothesis 5: Sustainable project success is supported by the definition of sustainability goals (h5a), the enhancement of project team toward sustainability (h5b), the planning for sustainability (h5c), the assessment of sustainability (h5d) and the implementation of stakeholder management (h5e).

These hypotheses were then empirically tested, as described in the next section.

## **2. Research methodology**

In order to test the hypotheses, the research involved the collection of empirical data from participants for the use of structural equation modelling (SEM). Targeted participants for the research were project managers or members of the project management team with more than two years of working experience in building projects in the UK, mainly projects with sustainability features or such sustainable certificates as green building, energy performance or low-carbon. An online questionnaire was selected as the data collection instrument. The questionnaire mainly consisted of close-ended questions; participants were required to evaluate success factors of SPM and SPS. A 5-point Likert-scale was used to elicit the level of agreement (1 = strongly disagree/very low, and 5 = strongly agree/very high) with the statements provided in each question. The questionnaire is delivered to participants by the social network, which is recognised as a potential approach to conduct a survey in social research (Kayam and Hirsch, 2012). The LinkedIn network is selected because a very high percentage of professionals in the UK (83%) use it as social media for career development (Trendence research, 2017). For quality assurance, only professionals with clear and suitable information of working history were invited to answer survey questions. Besides, questions in the participant's background information were used for quality control of the data collection.



Questionnaire responses were analysed using partial least squares structural equation modelling (PLS-SEM), which is a multivariate method of examining the cause-effect relationships between latent variables (Hair, Ringle and Sarstedt, 2011). PLS-SEM was considered the most suitable method for this study for three reasons: Firstly, it can solve complex hypothesis models like the one in this research, which has ten latent variables and 47 indicators. Secondly, PLS-SEM is powerful with small sample sizes, and it can run with non-normal data (Hair, Ringle and Sarstedt, 2011; Afthanorhan, 2013). Finally, PLS-SEM is a well-accepted method in construction management (Alzahrani, 2015; Carvalho, Patah and Souza Bido, 2015; Nagapan and Rahman, 2016; Banihashemi *et al.*, 2017; Carvalho and Rabechini, 2017).

After two months of data collection, the research obtained 144 valid answers. All the participants were experienced in directing and managing building projects. 86.2% of respondents had more than five years of experience in project management and execution, and 67.4% of them had more than ten years of such an experience.

### **3. Results**

PLS-SEM uses a bootstrapping procedure to generate 5000 samples from the observed data, and then they are used to test the significance of the path coefficients between variables. All hypotheses are tested at a significance level  $\alpha=5\%$ . Figure 1 summarises the hypotheses testing about the significance of path-coefficient. A higher value of path-coefficient presents for a stronger association between the two variables. The result shows that 10 out of 15 sub-hypotheses were fully supported at a significance level of 1% and five sub-hypotheses of the relationship between variables were not supported by the data collected.

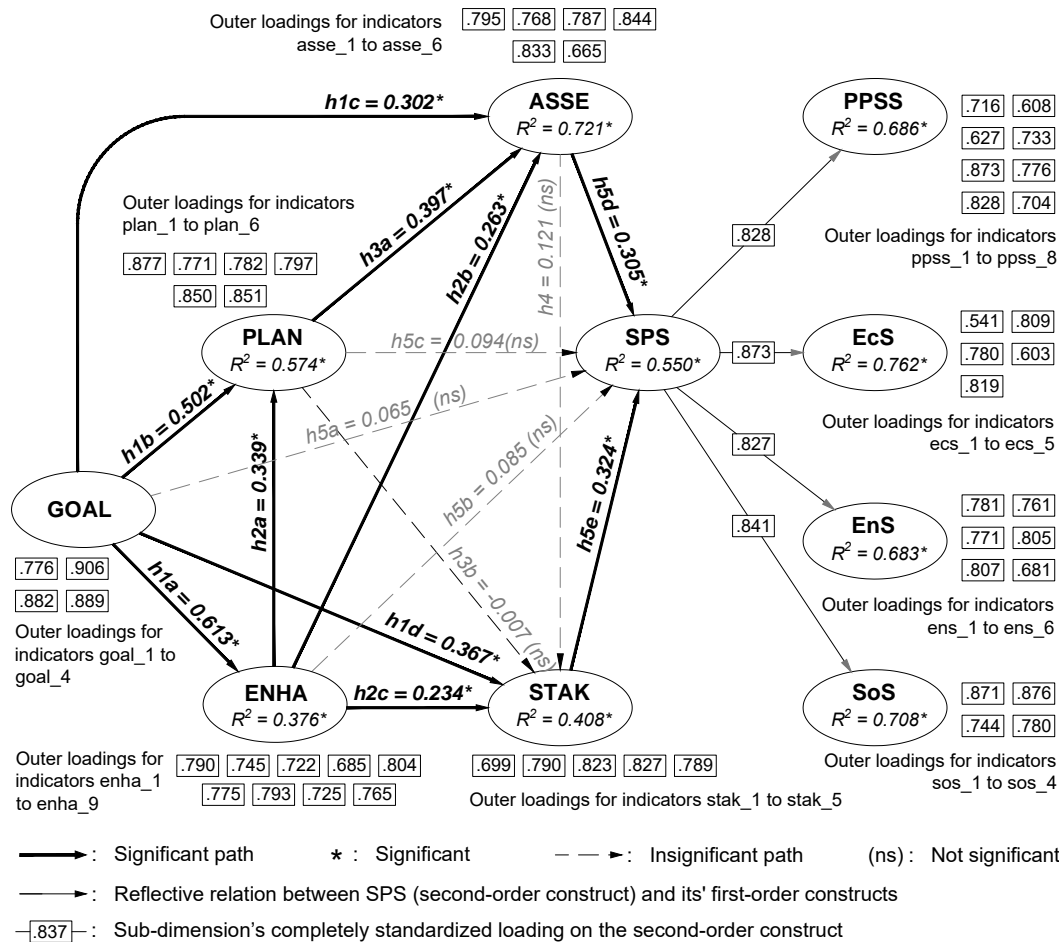


Figure 15: Types of relationships among latent variables of the testing model

#### 4. Discussion

The findings of this research support for the forming of Sustainable Project Management (SPM) with five key components, including sustainability goals definition, project team enhancement, sustainability planning, sustainability assessment and stakeholder management.

Results show that sustainability assessment and stakeholder management can support the achievement of Sustainable Project Success (SPS). However, the value of a sustainability goal, a competent team and a sustainability plan is still underestimated in the theoretical and practical points of view. This research sees the relationship between SPM and SPS with a metaphor of an apple tree (See Figure 2). From a first viewpoint, all the trees are in green, which is SPS. To grow the foliage of leaves, the value of sustainability assessment and stakeholder management are, actually, the core trunks of the tree. Indeed, they need strong taproots to work effectively. The taproots in this study highlight the definition of sustainability goals, enhancement of the project team toward sustainability, and the planning of sustainability in the project. Therefore, all approaches that focus solely on using a building rating system to evaluate the building's sustainability might not be sufficient.

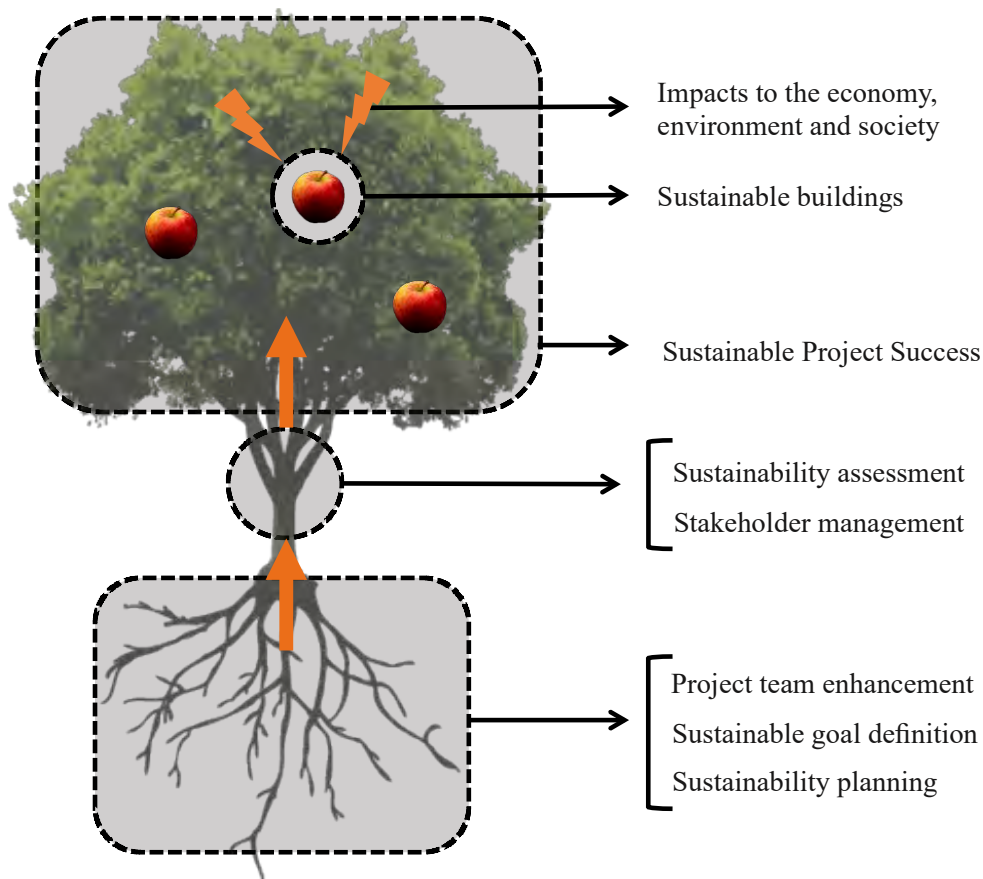


Figure 16: The apple tree of sustainability

*Sustainability goal and competent project team - An crucial initiation for achieving sustainability*

Both sustainability goals definition and project team enhancement have a positive and remarkable influence on all three remain components of SPM. This finding highlights the importance of these two components in the model. Although it can not fully support the opinion of Gareis (2013) that the project initiation process is more important than the project delivery process to achieve sustainability, it shows that activities in project initiation process are not less important than those in following stages. In other words, the further implementation of activities in project delivery (including planning, assessing of sustainability, managing stakeholder) needs a clear vision of project goals and a proper team to carry them out.

Moreover, path coefficient values pointing from [GOAL] are all higher from those toward the same constructs pointing from [ENHA] (See Figure 1). It means that the performance of stakeholder management, sustainability planning and assessment rely more on a project goal that facilitates sustainability than on the ability of the project team. It implies that the definition of sustainability has a critical meaning in the SPM model; the sustainability goal is the crucial starting point of a sustainable project. This finding is also in line with a recommendation from Eid (2004) that sustainability should be integrated into scope and objectives in the initial stages of the project.

The definition of sustainability goals also has a substantial high impact on the enhancement of project team ability toward sustainability. On the one hand, it implies that the definition of a sustainability goal at the beginning of the project allows getting a competent project team. On the other hand, the team with rich experience, high motivation, innovative thinking, learning ability, and collaboration can contribute to the success of sustainable projects. Therefore, the relationship between a sustainability goal and an enhanced-competent project team is a two-way relationship when they can support each other. The project manager is often restricted with traditional project constraints and limited power, and then an explicit goal of sustainability can free them to use all of their potential ability in managing stakeholder and in planning project toward sustainability.

Therefore, to ensure proper sustainability goals or objectives are set up in the project brief, it is highly recommended to appoint an experienced project manager at an early stage of the project. In many cases, clients of building projects do not have intensive experience and knowledge in the area of construction and sustainability. So the early involvement of the project manager can help to bridge clients to experience and knowledge of project managers in the sustainable construction of buildings. Through a discussion of benefits, opportunities and constraints of sustainability in the strategic definition stage, project managers can advise clients on sustainability features in their buildings. It also can help to meet the client's sustainable development strategies and regulation documents on sustainability. Besides, clients might use sustainability champions (which is often named as sustainability advisor, accredited professional or sustainability consultant) as their advisors on technical aspects of sustainability. Furthermore, the project manager is expected to motivate sustainability among the team. Brink (2013) showed that proper motivation could bring to positive emotions, which stimulate not only effective and efficient project management but also environmental behaviour.

#### *The critical value of stakeholder management and sustainability assessment to the achievement of sustainable project success*

Regarding the relationship between SPM and SPS, the result indicates that a higher level of stakeholder management and sustainability assessment are associated with the achievement of SPS. The positive relations between sustainability assessment and SPS is not surprising because the measurement is designed to ensure that final targets are met. However, it is interesting to note that stakeholder management has not less critical meaning than sustainability assessment in achieving the sustainable results of the building. As social sustainability is still blurred in many green building assessment tools and techniques, a focal point on stakeholder management can potentially fill the gap.

Therefore, this finding highlights the value of stakeholder management and that project managers should also pay more attention to this new area of project management knowledge in their sustainable buildings beside following a mean of sustainability assessment. Stakeholder management, in this case, should be implemented in a way that increases understanding about all stakeholders and their engagement with the project from the early stages through effective communication.

### *Sustainability planning can be underestimated in supporting SPS*

The sustainability planning process requires a sustainability management plan that could give further direction to activities in the delivery process of the project. This plan could be integrated into the regular project management plan, but as sustainability is not explicitly addressed in building projects, it should be a separate plan (Silvius, Neuvonen and Eerola, 2017). The latter approach is also in line with Project Sustainability Logbook in engineering and infrastructure industry from FIDIC (2013).

Multi-Case study research in the Netherland by Silvius, Neuvonen & Eerola (2017) demonstrated that the use of a sustainability management plan could potentially improve the project products. The SEM testing result (hypothesis h5c) shows that this relation might be fully mediated. Although sustainability planning does not directly support SPS, it support for sustainability assessment and sustainability assessment contributes to the achievement of SPS; then sustainability planning might indirectly support SPS. This indirect effect value might be relatively small as path coefficient values related to the third mediator (i.e. sustainability assessment) are not high substantial. The reason for this might be sustainability planning to be fully integrated into the regular project management plan. This discussion, therefore, believes that it could be more effective if a sustainability management plan is made as a separate plan before the project plan/project management plan is created.

## **5. Conclusion**

This study proposed a new theoretical model in sustainable project management in building projects and tested the hypotheses for the relationships between critical success factors for the achievement of sustainable project success. The study contributes to sustainability in project management by several key findings. Firstly, the research result supports the significant and positive impact of sustainability assessment and stakeholder management for achieving sustainable project success. However, sustainability assessment and stakeholder management are the core trunks of a sustainable tree; indeed, they need strong roots to work effectively. The roots in this study highlight the enhancement of the project team toward sustainability, the definition of sustainability goals and the planning of sustainability in the project - which can be explained by plain language as a proper target, a team and plan. It works in a way that an explicit goal of sustainability gives project team sufficient power and allow them to use proper abilities in managing stakeholder, in planning and assessment of project toward sustainability. Furthermore, sustainability plan can enhance the assessment of the sustainability of buildings. This finding implies that actions of merely applying a sustainability rating or evaluation might not be sufficient. Indeed, it needs support from a clear sustainability target, a competent project team and a proper sustainability management plan. Further studies could take advantages from the relationships identified in this paper to develop a guideline for project management team to manage sustainability in construction projects.

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# Challenges and Lessons Learned from Turnaround of INA Rijeka Refinery 2019

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## Abstract:

Turnarounds (TA) need a specific project management approach. Usually they reoccur every 3 to 5 years, depending on type of units, differences between sites and legal regulations. The main reasons for performing TA at INA Rijeka Refinery 2019 were increasing operational availability and reliability of refinery production facilities, improving energy efficiency and process security, but also engulfment of legal obligations. The strategic objective was to increase the re-occurrence period in INA from current 3 to every 4 years and with the next TA to every 5 years. Thus, the purpose of this paper is to show challenges and lessons learned from TA of INA Rijeka Refinery 2019. This case study paper describes planning and execution phases of 3 types of projects which were included in the TA: Capital Expenditure (CAPEX), Catalyst Replacement and Maintenance Activities. The paper first elaborates the planning phase consisting of: organization structure, scope and technology scheme, procurement and communication plan, project risks, review and schedule planning. During the execution phase we focus on risks and on-site monitoring as well as day-to-day reporting. Finally, the paper concludes with lessons learned and guidelines for improvement plan for the next cycle of INA TA.

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**Keywords:** Turnaround; Project; INA Rijeka Refinery; Lessons Learned; Oil and Gas; CAPEX

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## Introduction

A turnaround (TA) is a periodically plant shutdown to perform maintenance, repair, inspection and testing activities, but also replace process materials and equipment (Obiajunwa, 2007) to ensure productivity and reliability of the plant. The frequency of TA execution is between 3 and 5 years depending on a type of units, differences between sites and legal regulations (Emirs, 2014). According to Lenahan (1999; 2006), TA consists of four phases which are initiation, preparation, execution and termination (Lenahan, 1999; Lenahan, 2006) while Saho (2013) defines five phases of TA maintenance (TAM) process which are initiation, planning, executing, controlling and closing (Saho, 2013). Besides, a shutdown cycle is a never-ending cycle with planning, scheduling, operation and evaluation phases (Bijavank, 2004).

Basic TA goals are scope, quality, cost and time (Emirs, 2014) with minimal health and safety (HSE) or environmental accidents (Bijvank, 2004). Due to complexity of TA projects they experience many failures during execution while cost overruns and schedule delays are more than 20% whilst poor plant operability after startup is over 30% (Schroeder, Jackson, 2007). Moreover, major identified problems are high TA costs (TA costs and losses), short TA

duration, high TA risk, impeccable scope, limited workspace, resources constraints, scheduling problems (e.g. resource-constrained project scheduling problem – RCPS), etc. (Bijavank, 2004; Obiajunwa, 2012; Schroeder, Jackson, 2007; Saho, 2013; Lenahan, 1999). Lastly, TAM projects are specific for process industries like oil and gas, petrochemical, chemical, etc. (Obiajunwa, 2012) and need a specific project management approach (TAM management) which has been a topic of many studies. Emirs (2014) focused on development of the Project Management Office (PMO) adjusted for TAM projects (Emirs, 2014), Schroeder and Jackson (2007) suggested a usage of different risk management approach due to unique challenges in the oil and gas sector (Schroeder, Jackson, 2007) while Wenchi et al. (2015) indicated that the Value Stream Mapping (VSM) is a different management method which can improve efficiency of TAM projects by identifying process wastes (Wenchi et al., 2015). Moreover, application of new technologies in the TAM management was recommended (e.g. using Building Information Modeling (BIM) for construction lifecycle visualization and the more accurate scope definition) (Wenchi et al., 2015).

The biggest and the most complex TA at INA Rijeka Refinery was executed in 2019 so the purpose of this paper is to show challenges and lessons learned from this TA. This case study paper first describes project business case and then elaborates the planning phase consisting of organization structure, scope and technology scheme, procurement and communication plan, project risks, review and schedule planning. During the execution phase we focus on risks and on-site monitoring as well as day-to-day reporting. Finally, the paper concludes with lessons learned and guidelines for improvement plan for the next cycle of INA TA.

### Project Business Case

Main reasons for TA of INA Rijeka Refinery 2019 execution (figure 1, left) were increasing operational availability and reliability of refinery production facilities, improving energy efficiency and process security, but also engulfment of legal obligations. The strategic objective was to increase the re-occurrence period in INA from current 3 to every 4 years and with the next TA to every 5 years. Planned execution period of TA 2019, defined by refinery margins and market demands (which are usually lowest in this period of the year), was from beginning of January until mid-April 2019. Total investment was around €100 million.



Figure 1. TA of INA Rijeka Refinery 2019 (left) and column assembly – largest CAPEX project (right)

Based on INA organization as well as specificity of certain projects, all TA activities were divided into three different groups. First group was implementation of major Capital Expenditure (CAPEX) projects to increase efficiency and gain the environmental permit (figure 1, right). Second group was execution of Catalyst Replacement Activities which has ensured technological conditions for efficient production processes. Third group was execution of Maintenance Activities which contained engulfment of all legal obligations until next planned TA, replacement of critical equipment and other activities which should be realized during the refinery shutdown to maintain and improve safety and reliability of refinery operations. All projects which was selected for execution during TA 2019 were proposed through the internal INA procedure. For each project was prepared the separate document named *Individual Project Proposal* (IPP) with project details (scope, schedule, budget, benefits, risks, etc.) and was approved by INA *Investment committee*. Due to large number of proposed projects and increased risks during implementation, one of the most important criteria for projects' selection was condition of refinery shutdown for certain project execution.

## **Planning Phase**

Best World Practices recommend that planning of such a complex project must begin at least two years before realization. Thus, the first kick-off meeting for this TA was held in first quartile of 2017 when general objectives and goals of the event were defined, but also stakeholders for planning and execution phases were nominated.

### *1.1. Organization Structure*

Execution of all projects (TA related CAPEX, Catalyst Replacement and TA Maintenance Activities) during the refinery shutdown was managed as TA Event by temporary organization which was formed of three levels: *Steering committee*, *Main team* and *Team for execution*. *Steering committee* was the highest level in the organization, consisted of directors of various INA departments (procurement, investments, refinery, Single Service Company (SSC), etc.) with the role of making strategic decisions (e.g. TA execution period, procurement strategy, team nominations, etc.). SSC (named Integrated Technical Service – STSI) is a Limited Liability Company founded and in majority ownership by INA. The first kick-off meeting was actually the first Steering meeting while frequency of rest meetings during planning phase depended on planning stage of TA. *Main team* managed planning of TA and included Rijeka refinery managers together with local representatives of SSC. This team oversaw scheduling, cost monitoring, critical activities and risks defining, HSE, reporting to the *Steering committee* and daily issues managing. During planning phase the frequency of meetings gradually increase how TA was approached. Further, *Team for execution* was the operational group of experts from different areas which was responsible for defining detailed scope of works and technical aspects of the scope, scheduling and TA execution in general. According to refinery division there were three execution teams for each site area or groups of units (GP): GPA, GPB and Energetics and tank farm. Besides, the *Event manager* position was established whose main role was to coordinate planning and execution of all TA activities. Moreover, during planning phase detail Organizational Breakdown Structure (OBS) and each position description were developed (figure 2), but also several workshops were organized to increase awareness of all team members regarding their roles and responsibilities.

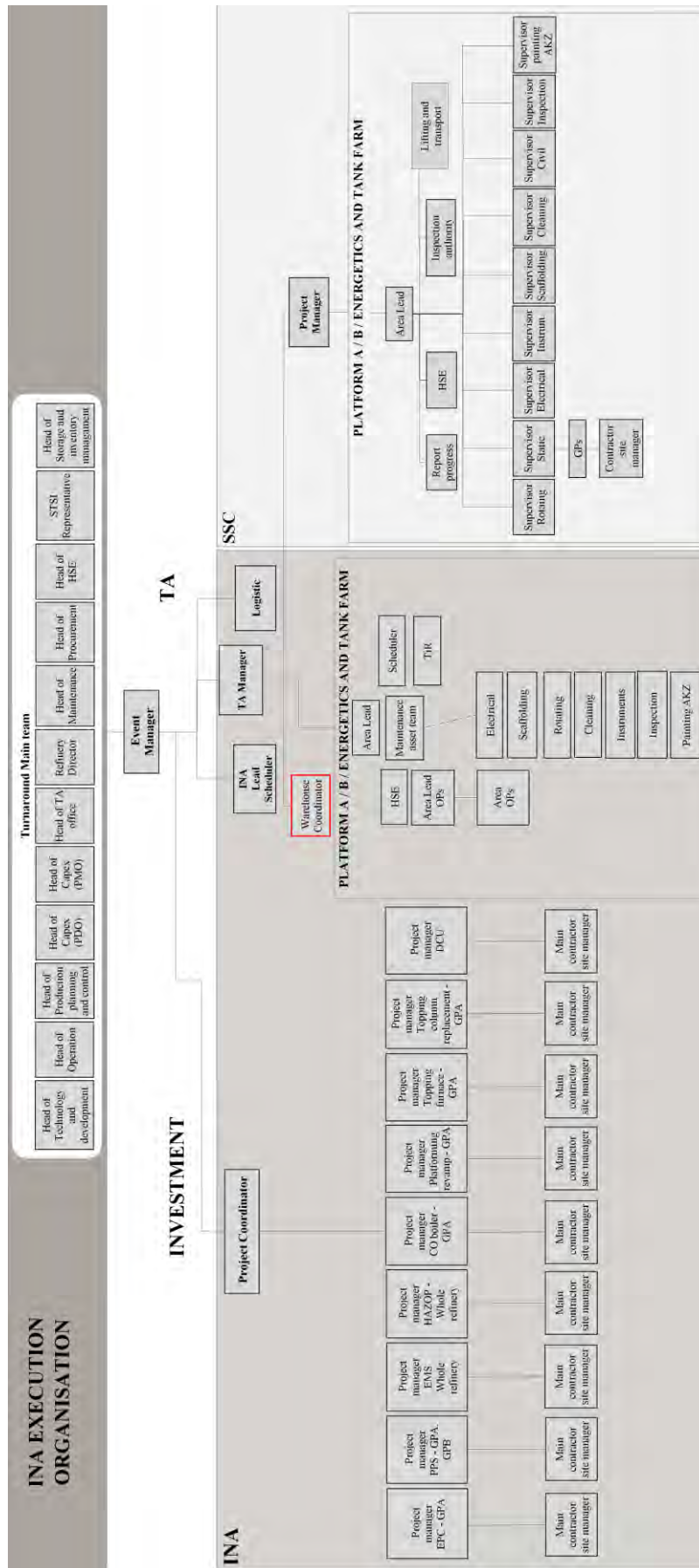


Figure 2. Organizational Breakdown Structure (OBS) for TA of INA Rijeka Refinery 2019

## 1.2. Scope and Technology Scheme

Selection of the scope was made by different approaches depending on the project complexity (Maintenance Activities or major CAPEX projects). Maintenance activities related to legal obligations engulfment have been repeatedly done in each TA while new activities were proposed by experts from maintenance and production departments. For each scope detailed explanation was proposed with all relevant information (e.g. detailed description of scope and recourses, cost estimation, risk assessment, additional documentation, benefits, etc.) and challenged by INA management and group level experts through *Cold Eye Review*. Thus, the initial scope of works (based on the TA scope management principles) was evaluated to ensure cost, reliability and duration optimization. Moreover, TA organization, structure for meetings and reporting, procurement strategy and TA risk management results were reviewed. Finally, main milestones and related status of TA phases were checked.

Regarding major CAPEX projects, scope selection was done by different approach called *Stage Gate Process* (figure 3). According to *Stage Gate Process*, the lifecycle of the project in INA has been divided into 6 phases with clearly defined responsibilities, activities for each phase and check points between them. The transition from one project phase to another depends on clearly defined criteria which set up input and output elements (Quality Assurance Review – QAR). First two stages of project initiation were under responsibility of Project Owner who had the full accountability for business case preparation and expected benefits after project realization. After gate 2 for each project was nominated Gatekeeper who was the representative of a permanent corporate organization. At the end of the selection phase, when a decision of project financing was made, the scope for the entire project must be clearly defined.

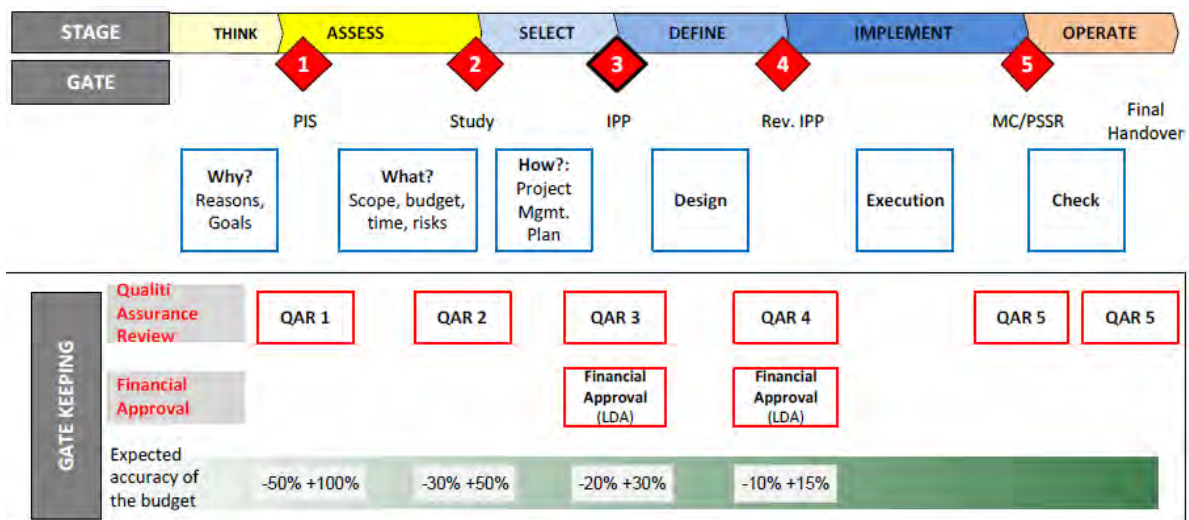


Figure 3. Stage Gate Process scheme

### 1.3. Procurement Plan

The *Procurement plan* consisted of three main sections. First was *Procurement plan information* which referred to the planned scope, value and time frame of the given procurement subject and was mainly defined by the Requestors. Data received from Requestors were consolidated and finalized by the Procurement department. Second was *Execution follow up* which defined main milestones of the procurement process, actual dates and other process relevant information. Third was *Contract information* which represented the contractual data as the outcome of procurement procedure. Success indexes related to the procurement procedure were also indicated in this section.

Procurement for TA event was done according to different approaches for maintenance part and CAPEX projects. Procurement member of *Steering committee* coordinated all procurement activities included in the TA. Whole concept for maintenance scope in INA was set on SSC principle and was realized through two different procurement strategies. On the one hand, tendering procurement process was conducted by available technical specification while on the other hand, services procurement was based on contract between INA and SSC. Besides, services connected with Long Lead Items (LLI) were realized through direct contracting with subcontractors. Materials and spare parts procurement for TA was also based on valid procurement strategy (part by SSC frame contract and part directly by INA).

Major CAPEX projects were generally contracted as *turnkey projects*. Competitive tender process was carried out for almost all CAPEX projects and was based on available technical specifications and the project documentation. Due to long life cycle of these projects, the procurement was usually done through three phases. Thus, first was open tender for project documentation preparation while technical solution team was evaluating profitability and impact on other projects. Second tender was usually done for purchasing equipment with long delivery deadlines. In some cases, equipment manufacturer was main contractor for equipment installation, but in most cases, due to specific equipment, companies were often specialized just for production process. Finally, last tender was done for on-site works. In this phase it was very important to include the whole TA scope on specific area to decrease number of contractors and ensure easier logistic organization.

### 1.4. Communication Plan

Communication is very important for keeping a project on task. Besides, poor communication processes cause time wasting and mistakes in decision making but also cost increasing. Furthermore, usual problem in previous TA was unclear communication when giving assignments and responsibilities. That was especially highlighted when external contractors were working in refinery for the first time. Based on previous experiences as well as recognized complexity of the whole event, consulting companies were included in TA planning to develop and implement functional communication plan with two focuses. First one was to optimize duration and content of daily operative meetings. Thus, list of topics for daily meetings and related durations were developed. Moreover, several workshops as well as meetings simulations with *Team for execution* members (area leaders and other participants) were organized to introduce a new organization of meetings. Second one was development of information flow hierarchy. Therefore, clear communication plan and information flow was created and presented on several workshops before TA execution had started. Example of communication loop is shown on figure 4.

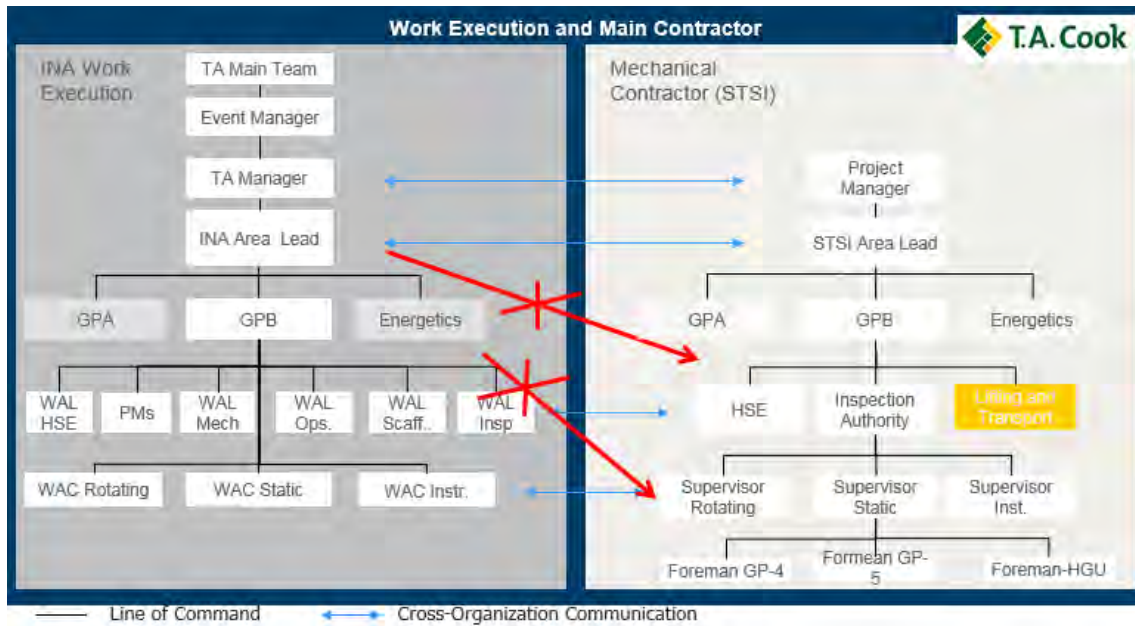


Figure 4. Example of communication loop (source: TA Cook Consultants)

### 1.5. Project Risks and Project Review

The definition of project risks was done for each project separately with all mitigation actions while risk register was created during projects initiation. Besides, risk evaluation for whole event was done by *Main team* after scope was frozen. Main project risks were categorized in several groups and for each group were proposed mitigation actions listed in table 1. First group of risks was weather conditions and according to analyses (for period January to March, years 2014 to 2017), around 23.4% of time, lifting operations could not be performed due to strong wind. Second group was recourse availability (internal and external) due to higher resources demand than available on the market, but also insufficient and inadequate internal recourses for complex scope preparation. Third group was execution of critical major CAPEX projects because some of them were on the critical path due to planned duration of execution. Fourth group was a TA logistic due to large number of workers and machineries included in execution as well as site terrain configuration. Fifth group was HSE risk because of large number of people on site, winter period of execution (which increase possibility for accidents) and issuing large numbers of working permits on the same time. The last group was overlapping between CAPEX projects and TAM activities because several projects have been executed on the same area, so overlapping risks were high.



Table 1. TA project risks and mitigation actions

Project risk	Mitigation actions
1. Weather conditions	<ol style="list-style-type: none"> <li>1. Implementation of weather conditions in common TA schedule (based on previous experience and historical data)</li> <li>2. Definition of activities which can be performed outside of the plant (e.g. pre-fabrications) to utilize time and recourses</li> <li>3. Adjustment of lifting operation in schedule based on priorities and criticality of projects</li> </ol>
2. Resources availability	<ol style="list-style-type: none"> <li>1. Scanning the availability of recourses on domestic and surrounding countries markets by procurement department</li> <li>2. Employment of new people and using recourses from other parts in INA</li> </ol>
3. Critical major CAPEX projects execution	<ol style="list-style-type: none"> <li>1. Daily status monitoring of most critical projects during TA</li> <li>2. Development of backup plans if project execution exceeded a planned TA period</li> </ol>
4. TA logistic	<ol style="list-style-type: none"> <li>1. Common logistic plan development to coordinate all project stakeholders</li> <li>2. Daily crane layouts development to ensure evacuation route</li> <li>3. Organizing additional facilities for lunch and entrances in refinery</li> </ol>
5. HSE risks	<ol style="list-style-type: none"> <li>1. Detailed HSE plan development as a part of TA logistic plan</li> <li>2. Implementation of HSE training center before starting works or entering the refinery</li> <li>3. Preparation of new training video materials</li> <li>4. Ensuring enough HSE certified recourses (internal and external)</li> </ol>
6. Overlapping between CAPEX projects and TAM activities	<ol style="list-style-type: none"> <li>1. Development of common schedule to coordinate all TA activities, optimize overlappings and maximize utilization of recourses</li> <li>2. Nomination of Area leaders who coordinated all activities on specific area</li> <li>3. Decreasing number of contractors in one area (using common contractors for TAM activities and CAPEX projects)</li> </ol>

INA engaged a consulting company to optimize event planning, compare readiness with Best World Practices, preform readiness review and monitor planning and execution phases. Readiness review was conducted through three phases while each review provided a gap analysis, recommendations and proposed support for closing these gaps. Used methodology for reviews was basic comparison with the Best Practices acquired on the projects with the same level of complexity (figure 5). During reviewing process stakeholders were interviewed while results as well as recommendations for improvement was presented to all of them.

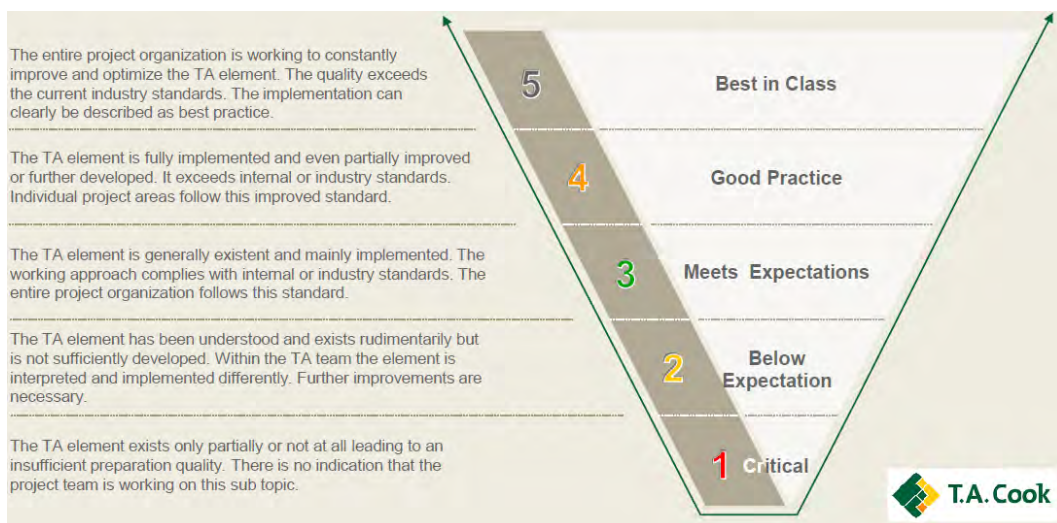


Figure 5. Best Practices used for comparison (source: TA Cook Consultants)

First review (TA scope review) was made in December 2017 with the focus on TA total scope definition. Main risks recognized during this review were: available number of resources and their skills quality, on time completion of CAPEX projects, overlapping of TA and CAPEX activities, permit process and weather (high winds). Second review (TA planning review) was conducted in June 2018 to analyse planning progress and procedures. Highlighted risks which could impact the TA were: late freezing of scope, CAPEX project level of details, logistic plan, training centre readiness and status of common schedule preparation. Third review was done in November 2018 when focus was on execution readiness. Top five risks recognized during this review were: available number of resources and their skills quality, on time completion of CAPEX projects, overlapping of works between TAM and CAPEX activities, issuing permit process and weather (particularly high winds). In order to decrease recognized risks, action plan was developed to implement recommendations and according to project review, results have improved since last time (readiness level for execution was improved – figure 6).

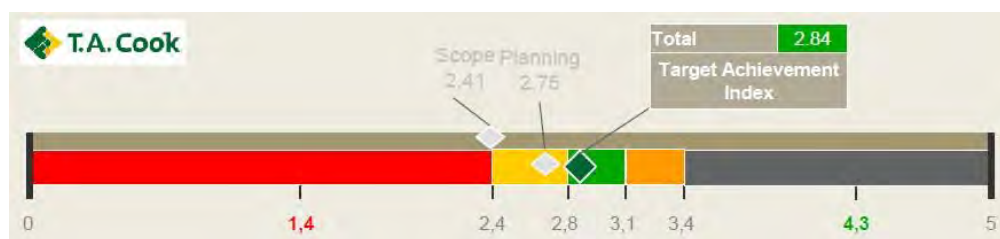


Figure 6. Results of Project review (source: TA Cook Consultants)

### 1.6. Project Schedule

The scheduling process was divided into three separate site areas according to the refinery division: GPA, GPB and Energetics and tank farm. Groups of units were divided into units, units into work packages and work packages into activities. Each activity had its own WBS name, activity ID, activity name, start date, finish date, original duration, activity percentage of complete, resources allocation and custom information (work center, number of work order, number of work permit application and planned number of executors). The final purpose of scheduling was defining activities with mentioned data and link them to get execution plan with optimal resources allocation. For that purpose, daily meetings were organized in Rijeka where participants defined activities and their durations. Besides, in schedule were added *buffer* activities to include unplanned maintenance activities for specific equipment (column, heater, heat exchanger and vessel). *Buffer* activities were separated to additional mechanical works, welding works, works with machining tools and technical control after repairs. All activities and their information were imported in Primavera P6 to get initial plan which included only technological links between activities within one work package. The second step was assigning resources and shift works by calendars to each activity. Resources were divided in groups which had their own resource ID and maximal units. With this information second version of plan was made using the technique *resources leveling*. When doing this, maximal units of each resource, project duration and priority of activity execution were limiting factors. Further, the basic maintenance works schedule was integrated with Management of Change (MOC) and catalyst replacement activities which

resulted in creating three separate maintenance plans. In order to get integrated schedule for refinery TA, CAPEX projects were implemented in scope. Schedules for CAPEX project were received from contractors in different forms (Primavera P6, Microsoft Project or Excel) and different levels of details. Since much overlapping could not be identified and agreed in the planning phase, there was not much corrections of master schedule due to CAPEX schedule integration.

## **Execution phase**

Execution phase started in January and finished in the mid-May 2019, which is about month more than planned duration of TA. Monitoring, controlling and reporting were key things when execution had started.

### *1.1. Risk and On-site Monitoring and Controlling*

During TA execution phase risks were monitored on daily bases. Daily area meetings were held at 10 am when all problems and risks which could not be handled by *Team for execution* were immediately escalated to *Main team*. Main team meetings were held at the end of the day where members (project authority) managed and tracked project risks, made decisions and risk mitigations. Besides, during execution phase Steering meetings were held on the request of *Main team*.

On-site works monitoring was done by dedicated team members depending on work disciplines. CAPEX projects supervision was generally done by main contractors in cooperation with project managers while maintenance works were supervised by SSC team members as well as INA supervisors. INA team members were responsible for technical solutions and the scope definition while SSC members were responsible for execution of works and recourse reallocation. Moreover, activities were coordinated on Area meetings and meetings with subcontractors. Further, as HSE risks during TA event were significantly higher than during normal refinery operation, additional recourses were engaged to supervise the safety regulations compliance.

Nevertheless, during execution several studies were conducted to: determine true *hands on tools* time (independent of task estimates, schedule and perception), identify root causes and patterns for reducing *hands on tools*, build up correlation between leadership behaviour, supervision and execution productivity, optimize available recourses, evaluate applied processes and management systems, compare planned estimates with a predefined set of reference data and create database for productivity improvement initiative. How *Hands on tools study* has proven as a great method for monitoring the performance of on-site works, contractors with biggest schedule delays were observed. Study results included also root causes and detailed analysis of activities execution. Most of lost time could be decreased with more efficient supervision (enough supervisors, quality of supervisions, etc.), so additional study was carried to evaluate the quality of supervisions as well as active supervision coaching before and during execution.

## 1.2. Reporting

Based on monitoring processes few reports were created during execution phase. First one was the daily HSE report regarding all irregularities on site prepared by HSE coordinators after their supervisions. Second report was prepared graphically due to terrain configuration and was necessary to coordinate all activities on daily basis and ensure evacuation routes. After Area meetings daily traffic plan and crane layout was sent to the all project stakeholders for day ahead (figure 7).

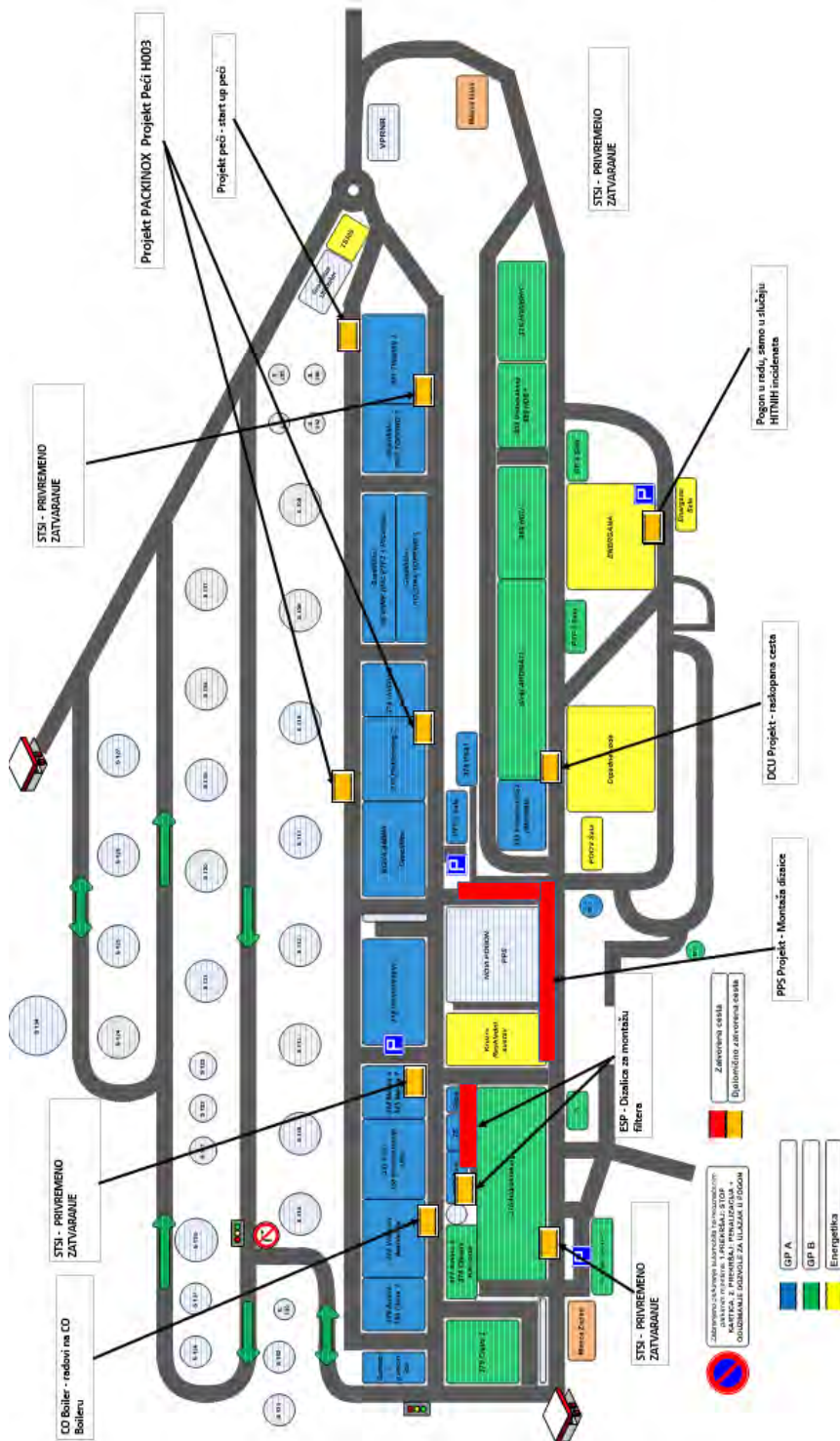


Figure 7. Example of Traffic plan and crane layout

Third one was Management progress report (MPR) which was, with inputs received from Area meetings, base for Main team meetings. MPR was made separately for GPA, GPB and Energetics and tank farm with idea to have all important information visible on one-page report. Thus, it contained S-curve tracking (total S-curve for TA and separately for main areas), HSE report, daily on-site manpower, critical works and activities, main risks and CAPEX project execution monitoring (figure 8). Moreover, progress of heat exchangers (which was identified as the most critical equipment) as well as different disciplines were tracking and reporting through MPR. Bases for MPR preparation was progress capturing and schedule monitoring.

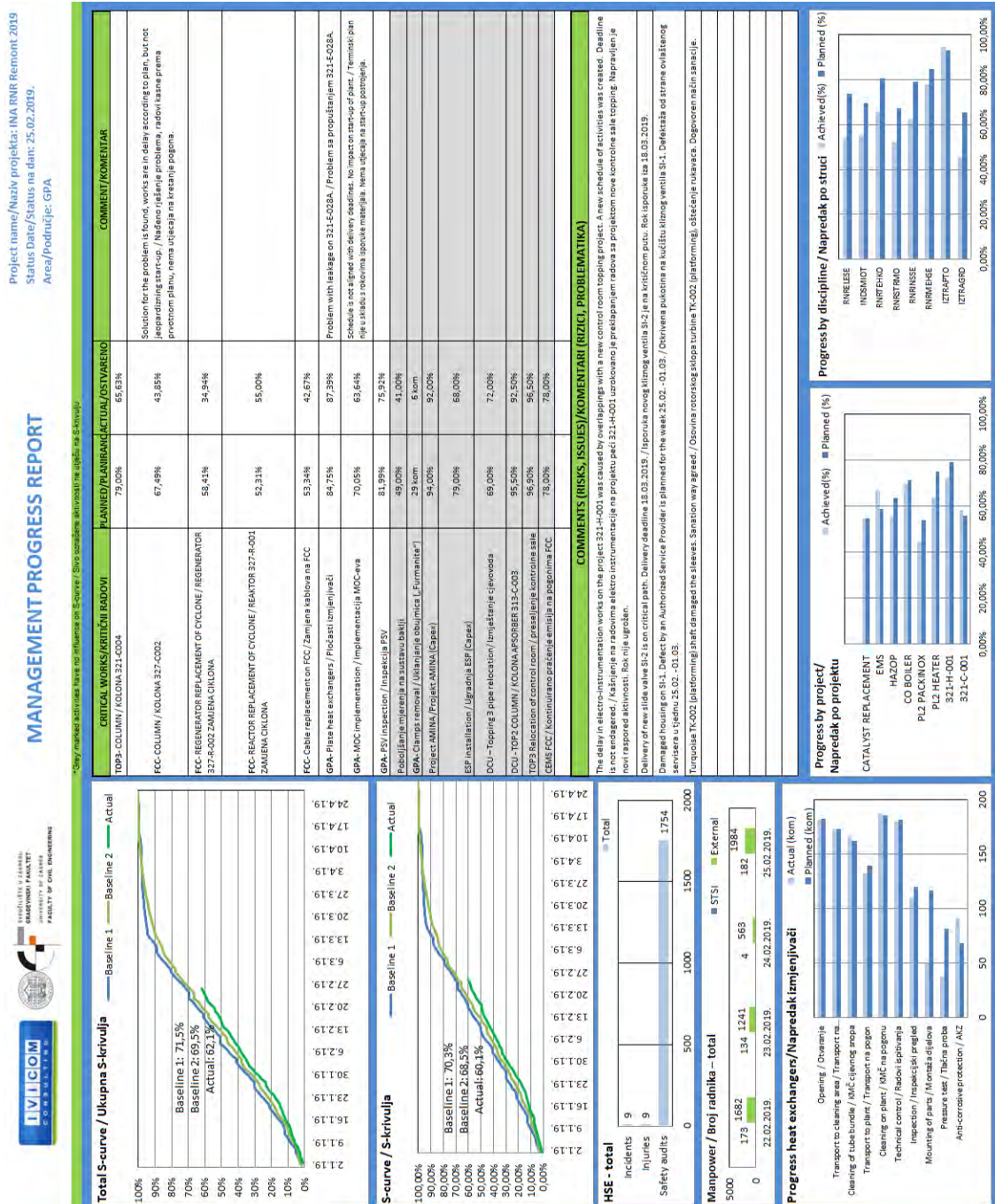


Figure 8. Example of Management progress report (source: IVICOM Consulting and Faculty of Civil Engineering Zagreb)

17 *hands on tools* studies, conducted on various contractors and different areas, showed an average productivity of 48% which is below best practices (figure 9). Although progress was evident after coaching there is still large space for productivity raising.

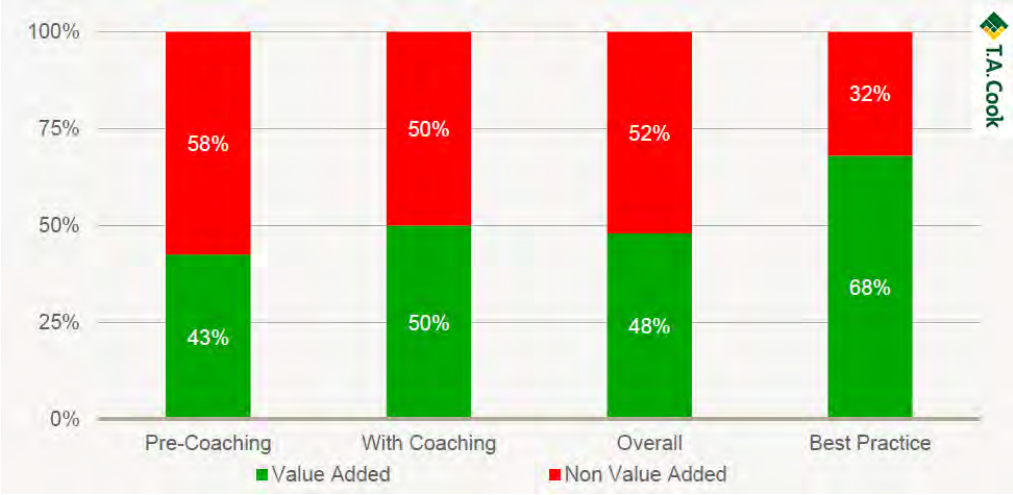


Figure 9. Comparison of TA productivity and Best Practice (source: TA Cook Consultants)

Regarding *Root causes analyses* of 52% non-value-added time, several root causes (resource planning, extra breaks, coordination, etc.) were repeated continually and had greatest impact on execution (figure 10). Thus, additional coaching and actions were taken to decrease their impact.

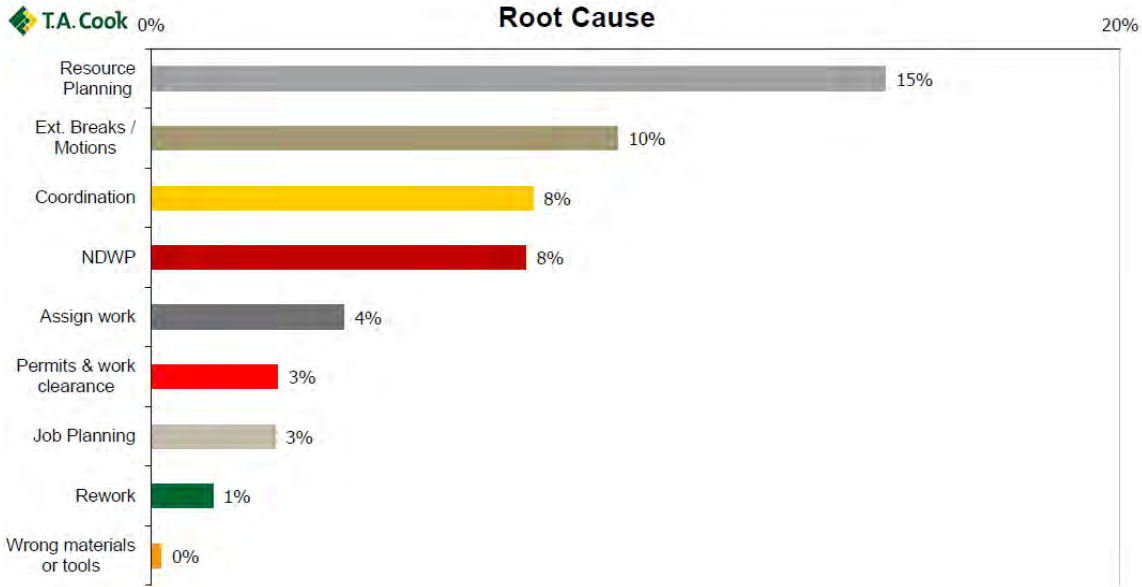


Figure 10. Results of Root cause analyses (source: TA Cook Consultants)

Main observations (figure 11) regarding supervision studies were that too much time was spent on administration works (34%) and that available time (4%) was less than Best Practice suggestion (10%). Available time has great impact on preparation for next day works.

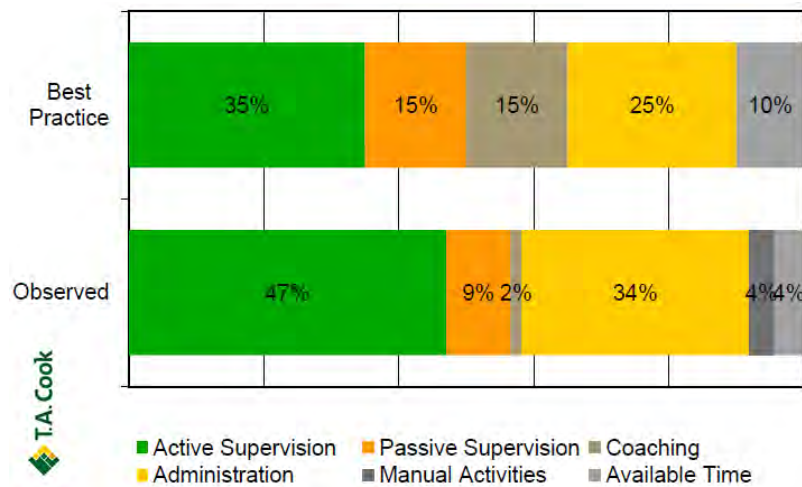


Figure 11. Results of Spent time analyses (source: TA Cook Consultants)

### Lessons Learned and Conclusion

During preparation and execution phases all detected problems and recommendations from all stakeholders and consulting companies involved in TA were collected and documented for processes improvement. As TA cycle is starting with past event post evaluation, all recommendations will be used to create the post evaluation report which will be presented to the top management. Part of post evaluation report is an action plan which contains all lessons learned description (during planning and execution phases of TA), impact of lessons learned on total event as well as mitigation actions with responsibilities and implementation deadlines. Lessons learned were categorized based on their impact on total event.

First category is a budget control. Budget ownership and awareness of additional costs must be increased between all stakeholders. Besides, expectations of top management (regarding costs) must be better communicated to all levels of organization. Moreover, setting of Key Performance Indicators (KPI) must be better aligned between stakeholders while different KPI's can cause collision between stakeholders' goals with impact on budget control. Further, control of additional works was not on satisfactory level while lot of additional works could be defined during planning phase of TA. Inadequate scope definition caused additional budget due to insufficient time for spare parts purchasing and negotiation process to get more favourable market prices.

Second one is technical scope and execution. Late and low-quality freezing of work scope caused many problems. Therefore, the final scope definition for such a complex project must be done earlier and should be clear to all project stakeholders. According to several reports, work productivity during execution phase was not on satisfactory level because lot of time was wasted on breaks, late starting and early finishing of works as well as over planned recourses for some activities' execution. Furthermore, decision making process was not fully in place, so time was wasting on a decision waiting. Lastly, lack of quality contractors and

supervisors caused time losing during execution phase as well as several problems during start up and refinery operation. Thus, quality of works must be improved.

Third category is schedule. As subcontractors were not included in schedule development, there were not consequences for maintenance works schedule delays for them. In addition, late and inadequate scope caused late start of schedule development which consequently disabled timely final schedule presentation to all project stakeholders. Further, schedules for major CAPEX projects and TAM activities were in different forms and level of details, so integration to one master schedule was difficult. Besides, schedule was generally not used for upcoming activities preparation which was highlighted on the area where TAM activities were overlapped with CAPEX projects.

HSE category includes improving of housekeeping which was not on satisfactory level and was most common reason for injuries during TA. Additionally, traffic solution on site, HSE education of subcontractor workers, working at heights and on-site workers tracking must be upgraded due to noticed irregularities and caused problems.

Last category is CAPEX projects, event organization and logistics. Firstly, better evaluation of CAPEX projects realization during defining phase (e.g. recourses and overlappings analyses), earlier appointment of TA Event manager position and involvement of key departments into the planning phase are needed. Nevertheless, the procurement strategy before contracting should include all scope of works on one area to reduce number of contractors. In addition, main CAPEX projects contractors should provide the evidence that all scope contracted between INA and main contractor is also contracted between main contractor and subcontractors (including scope and schedule compliance). Moreover, detail roles and responsibilities during startup must be defined in planning phase to avoid incidents and possible problems.

During TA of INA Rijeka refinery positive aspects of execution were also highlighted. Firstly, changes in usage of Enterprise Resources Planning (ERP) system were implemented which decreased administration works and enabled timely creation of work orders (before IPP submission). Moreover, budget was approved on time as well as budget changes by top management. Further, implementation of training center was showed as good base for TA planning and increasing quality of execution while turnkey contracting for TAM activities showed benefits in keeping budget, schedule and technical scope. In addition, tagging of flanges had positive impact during refinery start-up whilst scaffold mounting before TA execution improved recourses optimization and reallocation at the beginning of TA.

To conclude, according to TA execution analyses main issues were planned budget, duration and scope exceeding while reasons were undefined deadlines during planning phase, late and inaccurate scope freezing, problems during CAPEX projects realization as well as inadequate projects and stakeholders' coordination. Analyses also showed necessity of all company's project management processes unification and optimization using own INA's recourses and consulting companies. Next TA event is planned for first quartile of 2023, so first kick off meeting will be organized in second quartile of 2020 while special attention should be pay to prevent repetition of above problems. Therefore, tasks for kick off meeting are: Event manager nomination, approval of premise document (document which contain main targets of next event) and TA preparation plan, but also tracking of TA action plan realization.



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# **Publications in Croatian language**

# Produljenje rokova – penali s osvrtom na novi FIDIC 2017.

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## Sažetak:

Prilikom izvođenja radova temeljem ugovora o građenju često u praksi dolazi do situacija kada se prekoračuju ugovoreni rokovi, bilo međurokovi, bilo završni rok izgradnje. Stoga je i pitanje produljenja tih rokova relevantno pitanje u ovim ugovornim odnosima.

Naime, u praksi se pojavljuje pitanje tko je odgovoran za produženje rokova, te koje su pravne posljedice za ugovorne strane u slučaju prekoračenja tih rokova, kao i prava glede produženja tih rokova.

Jedna od tih pravnih posljedica je i ugovorna kazna, odnosno penali, a koji se ugovaraju u slučaju prekoračenja rokova. Često se u praksi pitanje penala promatra samo s aspekta broja dana kašnjenja i ugovorene vrijednosti za svaki dan, tj. izračunava se samo visina penala, dok se o osnovi zaključuje isključivo na temelju samog kašnjenja.

Međutim, svakako je potrebno i praksi utvrditi u svakom pojedinom slučaju i tko je odgovoran za kašnjenje, tj. prekoračenje rokova, a sve u duhu donošenja zaključka o osnovi za penale.

Ovo pitanje prava na penale, ali i prava na ostale zahtjeve između naručitelja i izvođača regulirano je i odredbama općih uvjeta FIDIC-a. Nova regulacija općih uvjeta FIDIC-a iz 2017. godine također ide u ovom smjeru naglašavanja značaja ovih zahtjeva, te se sada klauzula koja govori o potraživanjima Naručitelja i Izvođača odvaja u samostalnu klauzulu.

*Ključne riječi: naručitelj, izvođač, rokovi, penali, kašnjenje, FIDIC*

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## 1. Uvod

Cilj svakog projekta je osigurati uvjete za realizaciju u okviru financijskog plana, ali i u okviru predviđenih rokova. Jednako tako je i u slučajevima građevinskih projekata gdje je često u pitanju velika vrijednost radova gdje sudjeluje veći broj subjekata čija se prava i obaveze međusobno isprepliću. Pitanje izvedbe unutar ugovorenih rokova uvijek i nužno utječe na financijske odnose između naručitelja i izvođača, a ponekad i dalje u odnosu na projektanta i stručni nadzor.

Prekoračenje roka svakako je najčešći, a nerijetko i jedini razlog za obračun penala (ugovorne kazne). U radu se razmatraju različiti aspekti relevantni za ocjenu osnovanosti zahtjeva za naplatu penala, a sve kroz uvid u sudsku praksu i relevantne pravne izvore.

Jedan od razloga za kašnjenje, odnosno prekoračenje roka izvođača može biti i izvođenje naknadnih i nepredviđenih radova, a pri čemu nije moguće u pravilu zaključiti da su to razlozi koji predstavljaju krivnju izvođača.

Naša praksa tj. običaji nisu ustrojili jedinstvene rokove koji bi se mogli usuglašeno odrediti na točan dan, a što se može također razmotriti kao jedno od rješenja.

Pitanje penala se nerijetko površno pojednostavljuje i pokušava se tumačiti kao puki matematički izračun dana kašnjenja sa ugovorenim vrijednostima (postoci ili promili). Naravno da takav pristup nije dostatan i može samo uzrokovati vrlo skupe sporove.

Procedura ostvarivanja prava na naplatu penala analizira se posebno kao samostalan temelj za stjecanje ili gubitak tog prava.

Poseban osvrt daje se sukladno novoj regulaciji općih uvjeta FIDIC iz 2017. godine u odnosu na zahtjeve između naručitelja i izvođača. Obraditi će se i procedura u pogledu zahtjeva za plaćanje kao i zahtjeva za produženje roka obzirom na novu odredbu točke 20.1. FIDIC-a, te posljedice prekoračenja roka iz te točke.

## **2. Metodologija**

Prilikom izrade svog rada autor će se koristiti metodom uvida istraživanja pri čemu će se analizirati razna sudska praksa i praksa arbitražnog sudišta i to konkretno Stalnog arbitražnog sudišta pri Hrvatskoj gospodarskoj komori (dalje: SAS pri HGK). Navedeno iz razloga jer po prirodi stvari velika većina sporova iz FIDIC ugovora se rješava u arbitražnom postupku, a ne pred redovnim sudovima, obzirom da se ovakvim ugovorima predviđa arbitraža kao način rješavanja sporova među ugovornim stranama, a na što ugovorne strane u pravilu pristaju i ne mijenjaju ovu odredbu. Napraviti će se i metoda deskripcije i komparacije ove prakse sa osvrtom na pitanje kašnjenja i penala.

Također, prilikom izrade rada autor je bio i u izravnoj komunikaciji sa SAS pri HGK, a u pogledu javne objave njihove prakse, te je autor dao inicijativu da SAS pri HGK javno objavi na svojim službenim Internet stranicama odluke koje je SAS pri HGK donio u sporovima povodom FIDIC-a, te je SAS pri HGK dao pozitivan odgovor na ovu inicijativu, te se očekuje i objava ovih odluka. Za primijetiti je da su se sporovi i praksa po pitanju FIDIC ugovora pojavili unazad 10 do 15 godina, te da prije tog razdoblja nije niti bilo sudovanja u ovakvim sporovima.

Stoga se i prilikom usporedbe „starog“ i „novog“ FIDIC-a autor koristio empirijskom i komparativnom metodom pri čemu je razmatrao konkretne situacije s aspekta dosadašnjih iskustava po „starom“ FIDIC-u, obzirom da po „novom“ još nema dovoljan broj relevantnih primjera.

Odmah na početku ovoga rada autor ukazuje da ovaj rad nema cilj biti znanstveni rad, obzirom da niti sam autor nije znanstvenik, već eventualno može biti stručni rad, a u kojem se sam autor potrudio koristiti znanstvene metode radi bolje vjerodostojnosti zaključaka ovoga rada.

Autor će se u radu osvrnuti i općenito na pitanje tumačenja ugovora i utvrđenja ništetnosti ugovora, a sve obzirom na izmjene FIDIC-a iz 2017. godine kojima se sada prvi puta daje ovlast nadzoru da nadzor da procjenu opravdanosti produljenja ugovorenih rokova, te nadzor time ima

ovlast odlučiti kada je u pitanju prekluzivan rok kojim stranka gubi neko pravo, a kada rok nije prekluzivan.

### 3. Produljenje rokova

Ugovori o građenju posljednjih su se desetljeća razvili u složene ugovore kojima se postiže izgradnja kompletnih postrojenja kod kojih se zajedno izvode radovi građenja, isporuke opreme, pa i vođenja isporučenih postrojenja. Ti se složeni ugovori sklapaju u raznim oblicima, ovisno o stupnju odgovornosti pojedinih sudionika za krajnji rezultat, te se rokovi javljaju kao jedno od važnih pitanja u tim složenim ugovorima.<sup>2</sup>

Rokovi su vrlo važni, jer utječu na penale, ali još važnije od toga mogu utjecati na razlog za raskid cijelog ugovora. Na pitanje rokova se vežu mnoga daljnja važna pitanja kao npr. raskid, penali, odgovornost za štetu. U tom smislu bi svakako preporučljivo bilo ugovoriti pravne posljedice u slučaju nepoštivanja rokova vezanih za ugovor o građenju.

Navedeno iz razloga jer Zakon o obveznim odnosima (dalje: ZOO)<sup>3</sup> ne sadrži posebne odredbe vezane za rokove kod ugovora o građenju, dok Posebne uzance o građenju (dalje: PUG)<sup>4</sup> ukoliko se primjenjuju predviđaju terminske planove pa čak i međurokove, ali je potrebno ugovoriti pravne posljedice nepoštivanja tih rokova.

Međutim, čak i tada se mogu pojaviti određene nejasnoće kao primjerice ako se određuju penali na međurokove, postavlja se pitanje možemo li tada i obračunavati ih sukcesivno, odnosno ako se ne određuju penali na međurokove, treba li čekati kraj svih rokova da bi dokazali kašnjenje koje je očigledno nastupilo već ranije.

Izvori prava građenja su mnogobrojni i ne mogu se ograničiti samo na odredbe ZOO-a. Osim odredaba ZOO-a, pravo građenja djelomično je sadržano i u posebnim upravnim propisima o građenju, u općim uvjetima, uzancama, tipskim uvjetima, te konačno i u samim ugovorima.<sup>5</sup>

Određivanje rokova potrebnih za izvođenje radova iznimno je bitan dio odnosa između naručitelja i izvođača jer su kašnjenja u izvršenju radova, osim nedostataka u kvaliteti, najčešći uzroci sporova. Osim utvrđivanja vremena u kojem se radovi moraju dovršiti, također je vrlo bitno obratiti pozornost postupku koji se obično propisuje da bi se jednom utvrđeni rokovi produljili.<sup>6</sup>

U tijeku izvođenja građenja, ugovorne se strane neprestano nastavljaju dogovarati o svim onim pitanjima koja nemaju jasan odgovor u samom ugovoru ili o kojima je potrebno postići ponovni dogovor koji se odnosi na promjene u uvjetima i okolnostima građenja.<sup>7</sup>

Moguće je produženje ugovorenih rokova, pa se tako primjerice rokovi izvođaču mogu produžiti u slučaju kada je zbog promijenjenih okolnosti ili neispunjavanja obveza naručitelja

<sup>2</sup> Vukmir, B. (2009), Ugovori o građenju i uslugama savjetodavnih inženjera, RriF-plus d.o.o., Zagreb, str.4.

<sup>3</sup> Zakon o obveznim odnosima (NN 35/05, 41/08, 125/11, 78/15)

<sup>4</sup> Posebne uzance o građenju (Sl. list SFRJ broj 18/77)

<sup>5</sup> Gorenc, V. et. al. (2012.), Obvezno pravo Posebni dio I. Pojedini ugovori, Novi informator, Zagreb, str. 306.

<sup>6</sup> Vukmir, B., op.cit. (bilj. 1.) str. 455.

<sup>7</sup> Ibid., str. 121.

bio spriječen izvoditi radove. Također, jedan od razloga za kašnjenje izvođača može biti i izvođenje naknadnih i nepredviđenih radova, a pri čemu nije moguće u pravilu zaključiti da su to razlozi koji predstavljaju krivnju izvođača.

Rok sam po sebi uvijek ima vremensko određenje, i time dosta jasan odgovor na pitanje je li ta klauzula povrijeđena ili ne. Upravo zato treba oprezno ugovarati rokove ako nije jasan cilj koji se hoće postići u slučaju kršenja rokova, jer u protivnom stranke mogu imati sporniji odnos nego da nisu uopće precizirale rokove

Pitanje roka može se promatrati i sa stajališta je li riječ o bitnom sastojku ugovora ili rok nije bitan sastojak ugovora. Ovo je bitno i iz razloga jer u situacijama kada je rok bitan sastojak ugovora, a taj rok se ne ispuni, tada po samom zakonu (*ex lege*) dolazi do raskida ugovora. Takav stav je zauzeo i Vrhovni sud RH u svojim brojnim odlukama, te će se ovdje kao primjer spomenuti samo dvije. U svojoj odluci Rev-852/07 Vrhovni sud RH je zaključio da time što tuženik nije ispunio svoju obvezu uplate u roku za kojeg su utvrdili da je bitan sastojak ugovora, po samom zakonu nastupa raskid ugovora: „...takvo pravno stajalište ima temelj u čl. 125.st.4. u vezi sa st.1. istog članka ZOO-a. Naime, kad je ispunjenje obveze u određenom roku bitan sastojak ugovora, pa dužnik ne ispuni obvezu u tom roku, ugovor se raskida po samom zakonu. U takvom slučaju, prema stajalištu revizijskog suda, nije potrebna nikakva obavijest vjerovnika dužniku, jer je raskid ugovora nastupio po sili zakona.“<sup>8</sup>

Također, u svojoj odluci Revr-491/07, Vrhovni sud RH je zauzeo stav da ukoliko se smatra da je rok ispunjenja obveze bitan sastojak ugovora, tada se takva volja stranaka treba jasno i izričito navesti u samom ugovoru: „...iz odredbe čl. 125.st.4 jasno proizlazi da je riječ o fiksnom poslu u slučaju kad je u ugovoru određeno da je to volja ugovornih strana, što znači da stranke moraju izričito ugovoriti da je riječ o takvom poslu i da je ispunjenje u roku bitan sastojak tog ugovora – jer će se u slučaju neispunjenja obveze u određenom roku ugovor smatrati raskinutim. Također, drugi slučaj kad se smatra da je u smislu navedene zakonske odredbe riječ o fiksnom poslu je taj kad je rok bitan sastojak po prirodi posla.“<sup>9</sup>

U pogledu ugovora o građenju, ZOO nije izrijekom definirao bitne sastojke tog ugovora, odnosno koji su sastojci nužni za njegov nastanak, pa se može postaviti pitanje je li rok bitan sastojak ugovora o građenju. Ovo je bitno za utvrditi obzirom na gore opisane pravne posljedice ne postupanja u roku ukoliko je on bitan sastojak ugovora.

ZOO određuje i poseban rok u kojem je izvođač dužan obavijestiti svog podizvođača (podisporučitelja) o prigovorima koje je primio od naručitelja. Budući da podizvođač nije u izravnoj pravnoj vezi niti s investitorom, a niti s projektantom i nadzornim organom, to se njegova odgovornost može ostvariti samo preko izvođača s kojim je podizvođač vezan ugovorom. Ako izvođač namjerava od tih osoba zatražiti naknadu, na koju očito ima pravo prema istim načelima kao i na traženje naknade od projektanta, tada je dužan u roku dva mjeseca od dana kad je on sam obaviješten od naručitelja, o istom nedostatku obavijestiti podizvođača

<sup>8</sup> Vrhovni sud RH, Rev-852/07 od 30.01.2008. godine.

<sup>9</sup> Vrhovni sud RH, Revr-491/07 od 04.09.2007. godine.

(čl. 636.st.6.ZOO). Čini se da je ovo pravilo prisilne naravi i da se ovdje radi o prekluzivnom roku.<sup>10</sup>

Poseban uzrok mnogih spornih odnosa između naručitelja i izvođača je pitanje – koja ovlaštenja nadzorni inženjer ima u ime naručitelja, a prema izvođaču. Tumačenjem ZOO-a pravilan zaključak bi bio da nadzorni inženjer nije zakonski zastupnik naručitelja, niti ima ovlaštenja „po zaposlenju“ (jer nije zaposlen kod naručitelja), niti se ugovorom o građenju predviđa da bi on mogao u ime naručitelja ugovarati dodatne radove.

Nadzorni organ nije ovlašten odobriti isplatu izvedenih naknadnih radova niti njihovo izvođenje, jer je za svako odstupanje od projekta ili ugovorenih radova potrebna pismena suglasnost naručitelja radova. Naručitelj može tu suglasnost dati preko zastupnika, a nadzorno tijelo se ne smatra zastupnikom.<sup>11</sup>

Dodatno će se o ulozi inženjera u FIDIC ugovorima niže govoriti pod točkom 4.2. ovog rada, a sve obzirom da je izmjenama iz 2017. godine pojačana njihova uloga.

Uobičajena praksa pri realizaciji ugovora o građenju jest da nadzorni inženjer uz priznavanje tzv. više radnji i nepredviđenih radova zahtjeva i izvođenje naknadnih radova. Nerijetko nije moguće lako razlučiti predstavljaju li konkretni radovi nepredviđene radove koje je trebalo nužno izvesti iz tehnoloških razloga ili su to radovi koji moguće i nisu nužni, ali ih zahtjeva nadzor naručitelja.

U praksi izvođač nema uvjeta inzistirati na sklapanju novog ugovora ili aneksa ugovora, već prihvaća takav nalog nadzornog inženjera iako se nesporno radi o radovima koji nisu opisani u troškovniku (nisu „ugovoreni radovi“). Formalno su takvi radovi naručeni od neovlaštene osobe, te iako su izvedeni takav odnos predstavlja rizik za izvođača (ali teoretski i naručitelja), jer te radove ne prati nikakva ugovorna regulacija. Stoga bi kao rješenje, odnosno prevencija nastanka ovoga rizika bilo potrebno da naručitelj i izvođač već u ugovoru izrijekom definiraju ovlasti nadzornog inženjera.

Općim uvjetima FIDIC-a se što jasnije definiraju rokovi, a kojim se prekludira ostale sudionike u njihovim pravima, iako je u ovo pitanje prekluzije ponekada dvojbena. Ovo stoga jer je vrlo često u arbitražnim sporovima temeljem OU FIDIC-a pitanje kako pravno tumačiti prekoračenje roka od strane izvođača za predaju tzv. notice. Iako FIDIC ovdje ima jasnu odredbu, arbitri se u pravilu nađu u slijedećoj dilemi – je li pravno pravilno osloboditi naručitelja obveze čak i kad je tzv. claim izvođača opravdan, u velikim vrijednostima, ali je prethodno predan tzv. notice sa vrlo malim kašnjenjem u odnosu na propisanih 28 dana. Primjerice ako je riječ o kašnjenju dva dana. Međutim, dopuštanje takvog tumačenja dovodi do nesigurnosti gdje je granica, tj. zbog čega bi mogao kasniti dva dana i biti u roku, ali ako kasni primjerice 32 dana tada je izvan roka. Rješenje ovog pitanja nije moguće tražiti kroz opće uvjete FIDIC-a i njihova tumačenja. Rješenje je moguće jedino kroz definiranje posebnih uvjeta

<sup>10</sup> Gorenc, V. et. al., op.cit. (bilj.4.), str. 361.

<sup>11</sup> Crnić, I. (1997.), Zakon o obveznim odnosima s opsežnom sudskom praksom, Organizator, Zagreb, str. 527.

FIDIC-a gdje obje ugovorne strane imaju slobodno pravo same regulirati one odredbe općih uvjeta FIDIC-a koje same po sebi uzrokuju sporove.

#### 4. Ugovorna kazna

Uvijek se na pitanje rokova prirodno nadovezuje pitanje ugovorne kazne. Ugovorna kazna je pravno sredstvo kojim se stranke u ugovorima unaprijed zaštićuju od posljedica neizvršenja, zakašnjenja ili drugih propusta u izvršavanju ugovornih obveza. Naše pravo razlikuje ugovornu kaznu za neispunjenje obveze, za neuredno ispunjenje neke obveze te ugovornu kaznu za zakašnjenje u ispunjenju obveze. Ako nije posebno određeno u ugovoru za što se predviđa ugovorna kazna, smatrat će se da je ugovorna kazna ugovorena za zakašnjenje.

Ugovornu kaznu treba razumjeti kao vrlo životno pravo naručitelja tj. kao ono pravo koje naručitelj gotovo u pravilu konzumira ako ima ikakve uvjete na njega, a s druge strane u financijskom smislu korištenje tog prava u pravilu anulira bilo kakvu svrhu izvođača iz ugovora tj. anulira dobit izvođača.

Institut ugovorne kazne kod ugovora o građenju je vrlo bitan jer je taj institut gotovo nezaobilazan u svim ili gotovo svim ugovorima o građenju koji se odnose na važnije investicije.

Pitanje ugovorne kazne se nerijetko površno pojednostavljuje i pokušava se tumačiti kao puki matematički izračun dana kašnjenja sa ugovorenim vrijednostima (postoci ili promili). Naravno da takav pristup nije dostatan i može samo uzrokovati vrlo skupe sporove.

U ugovorima o građenju ugovorne su strane slobodne same odrediti hoće li ugovoriti ugovornu kaznu, za koje neispunjenje, ali i visinu ugovorne kazne te način njezina obračuna. Sukladno tome, ugovorna kazna može biti ugovorena ili u paušalnom iznosu ili u postotku od nekog drugog iznosa, može biti određena za neko vremensko razdoblje (npr. za svaki dan, tjedan ili mjesec zakašnjenja), a može biti ugovorena kao pribavljanje neke druge imovinske koristi. Visina ugovorne kazne prema ZOO-u prepuštena je dogovoru stranaka. Konkretno, u temeljnoj odredbi o ugovornoj kazni, članku 350. stavak 1. ZOO-a predviđen je uz zakašnjenje i neispunjenje i treći razlog za ugovornu kaznu – „neuredno ispunjenje“.

Također, niti PUG koje su trenutno na snazi nema na jasniji način definiranu ugovornu kaznu, već u uzanci 51. definiraju ugovornu kaznu na način koji je gotovo neprovediv, ako nije ugovorom jasno definirana. Razlog za ugovornu kaznu definiran kao „neuredno ispunjenje“ u konkretnom slučaju vrlo teško može biti usuglašen između naručitelja i izvođača. Kako su vrijednosti ugovorne kazne u pravilu ukupna dobit izvođača na tom poslu, jasno je da takvo uređenje sadašnjih uzanci vodi ka sporu.

Dakle, ukoliko ne postoji ugovorna regulacija što će se smatrati „neurednim ispunjenjem (što je vrlo često u praksi), teško je prema pravilima npr. građevinske struke ocijeniti što bi se u ugovoru o građenju smatralo – neurednim ispunjenjem. Stoga, upravo ovaj razlog „neuredno ispunjenje“ bez ugovornog određenja što bi se pod time smatralo, u pravilu vodi naručitelja i izvođača u neusklađen odnos.

Iz gornjeg je razvidno da je pitanje određenja razloga za ugovornu kaznu važno, jer o tom pitanju – koji je razlog za ugovornu kaznu, ovisi i ocjena jeli zahtjev naručitelja osnovan.



Sporazum o ugovornoj kazni prema ZOO-u (čl. 352.st.2.) „gubi pravni učinak“ ako je do neispunjenja, neurednog ispunjenja ili zakašnjenja došlo iz uzroka za koji dužnik ne odgovara.

Također, sudska praksa je zauzela i stav da se ugovorna kazna može obračunati samo ako je ugovor još uvijek na snazi, tj. nije raskinut. Takav stav je primjerice zauzeo Vrhovni sud RH u svojoj odluci Rev-208/06 gdje je izrijekom naveo da: „...ukoliko je ugovor „osiguran“ ugovornom kaznom raskinut, a kao što je ovdje slučaj, nema mogućnost ostvarivanja prava na ugovornu kaznu, pošto je raskidom tog ugovora prestala svrha u koju je ugovorna kazna bila ugovorena (ugovorna kazna je bila sredstvo osiguranja ispunjenja obveze iz ugovora). Zato, a kada je tužitelj raskinuo ugovor sklopljen s tuženicima, ne pripada ga potraživati isplatu ugovorne kazne.“<sup>12</sup>

Međutim, ovo isključenje primjene ugovorne kazne u slučaju raskida ugovora ne predstavlja nužno i isključenje unaprijed određenog iznosa naknade štete, a o čemu je Vrhovni sud RH zauzeo stav u svojoj odluci Revt-304/11 gdje je zaključio da se stranke mogu usuglasiti o iznosu naknade štete i nakon raskida ugovora, pa tako kaže: „...u slučaju raskida ugovora ugovorne strane ovlaštene su svoja prava i obveze urediti drukčije nego što ih uređuje odredba iz čl. 132. ZOO-a jer se radi o dispozitivnoj pravnoj normi. Slijedom toga, spornom odredbom iz čl. 2.t.10. ugovora o prodaji dionica stranke su zapravo ugovorile unaprijed utvrđeni iznos naknade štete počinjene ponašanjem kupca pa tuženiku pripada pravo zadržati taj iznos.“<sup>13</sup>

Vezano uz kašnjenje kao razlog za ugovornu kaznu, u većini slučajeva tijekom izvođenja radova pojavi se potreba naručitelja za tzv. izvantržovničkim radovima. Takvi radovi se kako je prethodno naznačeno u pravilu posebnim ugovorima ne ugovaraju, a najčešće utječu na rok ugovorenih radova. Nadalje, tijekom izvođenja radova radovi jednog izvođača ovise o radovima drugih izvođača. Pitanje istodobnog ispunjavanja obveze naručitelja u vidu plaćanja radova, može također biti neovisni razlog za otklanjanje odgovornosti izvođača za kašnjenje.

Važno je stoga i pravno praćenje izvođenja radova, te pravodobno i pravilno podnošenje zahtjeva za produljenje rokova (neovisno hoće li isti biti prihvaćeni), kao i evidentiranje svih relevantnih događaja kroz građevinski dnevnik i neposrednu pisanu korespondenciju između izvođača i naručitelja. Ispravno i sustavno vođenje dokumentacije preduvjet je za dobivanje sporova iz ugovora o građenju. Arbitri i suci, koji nemaju nikakvo izravno saznanje o događajima i činjenicama, oslanjaju se samo na pisane dokaze. Svako pismo odaslano za vrijeme odvijanja radova ima snagu dokaza i to mnogo uvjerljivije od onoga što piše u kasnijim tumačenjima u arbitražnom postupku.<sup>14</sup>

Odgovornost svakog od navedenih sudionika u građenju, utvrđivat će se na temelju njihove uloge u postupku građenja, a u cilju utvrđivanja njihove „krivnje“ za učinjeni propust ili štetu. Njihova se odgovornost utvrđuje „razmjerno njihovoj krivnji“.

<sup>12</sup> Vrhovni sud RH, Rev-208/06 od 16.03.2006. godine.

<sup>13</sup> Vrhovni sud RH, Revt-304/11 od 04.04. 2012. godine.

<sup>14</sup> Vukmir, B., op.cit. (bilj.1.), str. 11.

Dokazivanje međusobnih odgovornosti nije nimalo jednostavan zadatak. U slučaju sporova, sudovi i arbitraže bit će stavljeni pred tešku zadaću utvrđenja uzroka nekog nedostatka, a posebno razmjera krivnje pojedinih sudionika u gradnji.

Pitanje prekoračenja rokova izvođenja radova nerijetko ugovorom predviđa nemogućnost daljnjeg financiranja investitora, a što za njega nije povoljno rješenje radi čega on kao naručitelj formalno prihvaća produljenje roka. Time ujedno sebi načelno uskraćuje mogućnost za postavljanje zahtjeva za ugovornu kaznu, budući je ispunjenje u produljenom roku, ispunjenje u roku.

Ugovorna kazna se obračunava (ili se najavljuje njihovo terećenje) u svim ugovorima veće vrijednosti. Razlozi tome su da se u pravilu vrlo mali broj ugovora doista izvrši u ugovornom roku. Naručitelj, a naročito krajnji investitor, u pravilu ne propušta prigodu na okončanom obračunu izjaviti prijeboj i na taj način umanjiti svoju obvezu. Međutim, zbog toga što je nominalno prekoračen rok izvođenja, ne znači da je isključiva krivnja za sve dane prekoračenja na strani izvođača. Analiza koji sve uzroci kašnjenja mogu biti i za što je izvođač tražio, dobio ili je trebao dobiti opravdano produljenje, tipična su pitanja koja se mogu pojaviti tijekom građevinskog spora.

Osim propisivanja ugovorne kazne, kao kazne za ugovorne stranke, ugovorom o građenju moguće je dogovoriti i određene ugovorne bonuse za raniji dovršetak radova u korist izvođača, što se u ugovorima koji se sklapaju rijetko koristi. Tako bi i ugovorni bonusi mogli biti eventualno točka prijepora između stranaka u smislu jesu li se ostvarile pretpostavke iz ugovora za ostvarivanje ugovornih bonusa ili ne, koji su iznosi predviđeni kao iznosi ugovornog bonusa itd.

Budući da je ugovorna kazna lako određiva, a kako su mjerila redovito sadržana u ugovoru, teret dokaza za osporavanje njezine visine ili njezine osnovanosti prebačen je na dužnika. Ako dužnik tvrdi da vjerovnik nema pravo na ugovornu kaznu ili da je ugovorna kazna previsoka, mora to i dokazati.

Da bi vjerovnik zadržao pravo na ugovornu kaznu za zakašnjenje ili za neuredno ispunjenje, u slučajevima kada je primio ispunjenje obveze usprkos zakašnjenja ili neurednog ispunjenja, potrebno je da „bez odgađanja“ priopći dužniku da zadržava svoje pravo na ugovornu kaznu. Ako ne bi tako postupio, smatrat će se da je izgubio pravo zahtijevati ugovornu kaznu (čl. 353.t.5. ZOO).<sup>15</sup> Na jednak način postupio je i Visoki trgovački sud RH koji je u svojoj odluci Pž-4049/02 zaključio da: „...na ovaj način je u ZOO-u propisano da vjerovnik gubi pravo na ugovornu kaznu zbog zakašnjenja ako je primio ispunjenje obveze, a nje bez odgađanja priopćio dužniku da zadržava svoje pravo na ugovornu kaznu (čl. 273. ZOO-a). Naručitelj je potpisao Zapisnik o ponovnom pregledu, primio je okončanu situaciju koja se sastavlja i podnosi na naplatu nakon primopredaje izvedenih radova (uzanca 62.st.2.), platio ugovornu vrijednost radova i nema dokaza da je na bilo koji način saopćio dužniku da zadržava

<sup>15</sup> Jednako tako stav zauzima i primjerice Županijski sud u Bjelovaru, Gž-2249/2012 od 17.01.2013. godine.

svoje pravo na ugovornu kaznu. Time je izgubio pravo zahtijevati isplatu ugovorne kazne, bez obzira što je nesporno da je bilo zakašnjenja izvođača u ispunjenju obveze izvođenja radova.“<sup>16</sup>

U praksi se kao sporno pitanje pojavljuje i do kada naručitelj može podnijeti izvođaču zahtjev za naplatu ugovorne kazne. Sadašnje uzance neopravdano taj rok izvođaču ostavljaju do „završetka konačnog obračuna“. Svakako da je takvo rješenje iniciralo mnoge sporove, jer je naručitelju dalo prekomjerno pravo – da drži u neizvjesnosti izvođača nakon primopredaje radova u pogledu financijskog protuzahjtjeva.

Arbitražni sud SAS pri HGK je u jednom svom pravorijeku zauzeo stav da „... tuženik nije zakasnio s davanjem izjave da će naplatiti ugovornu kaznu, kako to smatra tužitelj, jer ju je dao najkasnije prilikom sastanka održanog radi konačnog obračuna, što je u skladu s Uzancom br. 55., prema kojoj se zahtjev za ostvarivanje prava na ugovornu kaznu može podnijeti najkasnije do završetka konačnog obračuna. Činjenica da su predstavnici tužitelja napustili sastanak te nisu potpisali Zapisnik o okončanom obračunu ne utječe na pravo tuženika na naplatu ugovorne kazne.“

Konkretno, prema uzanci 55., zahtjev za plaćanjem ugovorne kazne „...može se podnijeti najkasnije do završetka konačnog obračuna“. Iz te bi odredbe proizlazilo da se prema PUG-u ne traži davanje obavijesti bez odgađanja o zadržavanju prava na ugovornu kaznu u času kada se radovi preuzimaju ili u času neurednog ispunjenja, nego da je to moguće učiniti do završetka konačnog obračuna.

Izjava o zadržavanju prava na ugovornu kaznu mora se dati izričito i na nedvojben način; npr. Zapisnička konstatacija prilikom primopredaje objekta da je izvođač zakasnio s izvođenjem radova nema značenje izjave da investitor zadržava pravo na ugovornu kaznu, ako to izričito u zapisnik ne upiše riječima; zadržavam pravo na isplatu ugovorne kazne i tražim da mi se isplati (obračuna) od strane izvođača radova, jer je kasnio s donošenjem radova, te su se stekli uvjeti iz ugovora, za naplatu ugovorne kazne u korist investitora.<sup>17</sup>

Prema OU FIDIC smatra se da naručitelj ima pravo na ugovornu kaznu i u slučajevima kada je izvođač zatražio ili naručitelj odobrio produljenje rokova. No, naručitelj će izgubiti pravo na ugovornu kaznu ako spriječi produljenje rokova na način da ne odgovori na zahtjev izvođača u roku od 42 dana koji je određen u čl. 20.1. (predzadnji stavak).

U ugovorima o građenju obično se razlike kod ugovaranja ugovorne kazne razlikuju u pravilu samo u oznaci visine tj. promila po danu zakašnjenja kao i kroz oznaku ukupnog postotka visine kazne u odnosu na vrijednost ugovornih radova. Ako stranke ugovorom odrede obvezu plaćanja ugovorne kazne, ali ne odrede njezinu visinu, odredba ugovora o ugovornoj kazni je pravovaljana, a stranke se o visini mogu naknadno sporazumjeti. U slučaju da se ne sporazume, visinu će odrediti sud na temelju svih okolnosti konkretnog slučaja.

Obično se ugovorna kazna ograničava kroz mogućnost obračuna do 10 dana (npr. 5 promila i 5 posto) ili najviše do 200 dana (0,5 promila i 10 posto). Načelno su to najniži i najviši limiti

<sup>16</sup> Visoki trgovački sud RH, Pž-4049/02 od 12.07.2015. godine

<sup>17</sup> Tonković, P. (2001.), Odgovornost projektanta i graditelja za nedostatke građevine, Croatiaknjiga, Zagreb, str. 156.

prema kriteriju uobičajenih vrijednosti, obzirom da prisilna zakonska norma uređuje samo gornji limit ugovorne kazne, dok donji limit nije ničime određen pa je na dispoziciji stranaka kako će ugovoriti.

Također, kriterij gornje vrijednosti ugovorne kazne je limitiran i odredbom ZOO čl. 354. koja uređuje mogućnost dužniku ugovorne kazne da zahtjeva od suda smanjenje ugovorne kazne ukoliko je ista „suviše visoka“.

U tom smislu moguće je u praksi dogovoriti da bi ugovorne kazne iznad 10% vrijednosti ugovora bile rizične kod tumačenja jesu li suviše visoko ugovorene, te je za procjenu koja je to „suviše visoka“ ugovorna kazna relevantno utvrditi pojedinačni ugovorni odnos i sve okolnosti tog odnosa, kao i konkretan razlog za obračunavanje iste.

U pogledu utvrđenja visine ugovorne kazne moguće je da se pojavi kao sporno i koja je to osnovica za obračunavanje ugovorne kazne, ako stranke nisu ovo ugovorile, s tim da se najčešće ugovara da je to upravo vrijednost ugovorenih radova, što također može biti nejasno u slučaju složenijih građevinskih objekata kada je ugovarano izvođenje po fazama.

## **5. OU FIDIC 2017.**

Na svojoj godišnjoj konferenciji korisnika održanoj 5. i 6. prosinca 2017. godine u Londonu Međunarodno udruženje konzultantskih inženjera (FIDIC) izdalo je svoju Zbirku ugovora – FIDIC 2017, koje se sada sastoje od 21 članka Općih uvjeta ugovaranja, umjesto dosadašnjih 20.

FIDIC-ovi novi ugovorni uvjeti zamjenjuju poznatu FIDIC 1999 Zbirku ugovora FIDIC je izdao revidirano izdanje svoje međunarodno priznate zbirke ugovora "Dugine zbirke", odnosno Crvene knjige (Građevinski i inženjerski radovi), Žute knjige (Postrojenja i projektiranje i građenje) te Srebrne knjige (Inženjering, nabava, građenje/Projekti "ključ u ruke").

Osnovna namjera većine izmjena je povećati jasnoću i preciznost kako bi se smanjio rizik neslaganja te tako povećala vjerojatnost uspješnih projekata. Naime, ovim izmjenama htjelo se stvoriti osnovu koja će smanjiti broj potencijalnih sporova. Međutim, upitno jesu li ove izmjene pravi smjer za unapređenje ugovorne prakse ugovornih strana. Ovo ponajprije jer ovakvi detaljni dokumenti otežavaju ugovornim stranama da u potpunosti razumiju ugovor i da ga primjenjuju u svakodnevnom izvršavanju. Također, što je složeniji ugovor, veći je i rizik pojavljivanja sporova u pogledu tumačenja primjene odredbi tog ugovora. Dodatno ovi nesporedumi mogu proizaći i iz činjenice manjkavog prijevoda obrazaca tih ugovora obzirom da su isti na engleskom jeziku.

Sa stajališta primjene našeg zakonodavstva, kada su OU FIDIC sastavni dio nekog ugovora na koji se primjenjuje hrvatsko pravo, tada se na takav ugovorni odnos primjenjuju i odgovarajuće odredbe ZOO-a.<sup>18</sup>

<sup>18</sup> Vukmir, B. (2013), Kratki komentari FIDIC-ovim općih uvjeta građenja, RriF-plus d.o.o., Zagreb, str. 12.

### 5.1. Ključne promjene

Brojne ključne promjene za napravljene kako bi dovele do smanjenja broja sporova, kao što je pojačana uloga Vijeća za rješavanje sporova (DAAB) te podjela procedure u odnosu na zahtjeve (claim) i u odnosu na sporove (dispute). OU FIDIC također uključuju detaljnije propisanu proceduru i vremenske rokove u pogledu zahtjeva i sporova, a što će potencijalno povećati administrativne obveze u pogledu praćenja za obje ugovorne strane i za inženjera (engineer). Također je promijenjena i procedura za zahtjeve (claim) Izvođača (contractor) i Naručitelja (employer).

Razdvajanjem odredbi o proceduri povodom zahtjeva i sporova u novim OU FIDIC iz 2017. godine naglašeno je da se zahtjev jedne ugovorne strane može riješiti bez da dođe do spora između stranaka, tj. time se želi prevenirati spor, jer se strankama daje mogućnost da što ranije pokušaju riješiti bilo kakve potencijalne sporove i na taj način i spriječiti njihov nastanak. Ostaje za vidjeti hoće li u praksi uistinu ove odredbe i dovesti do smanjenja broja sporova među ugovornim stranama, ili će upravo suprotno ove odredbe biti podloga za nove sporove kakvih do sada nije bilo.

Konkretno, nastavno na gornje, za naznačiti je da je ranija klauzula 20. Potraživanja, sporovi i arbitraža podijeljena na klauzulu 20. Potraživanja Naručitelja i Izvođača (Employer's and Contractor's claims) i klauzulu 21. Sporovi i arbitraža (Disputes and arbitration) - Potraživanja Naručitelja više nisu dio klauzule 2., jer se o njima sada govori, kao i o potraživanjima Izvođača u klauzuli 20.

Podklauzula 20.2. Zahtjevi za plaćanje i / ili EOT – zahtjev za produženje roka (Claims For Payment and/or EOT) detaljno propisuje proceduru koja se treba poštovati kada Investitor i Izvođač podnose zahtjeve u vezi vremena i/ili novca. Ako je prvobitni odgovor Inženjera (prema Crvenoj ili Žutoj knjizi iz 2017. godine) ili druge strane (prema Srebrnoj knjizi) da je Obavještenje o potraživanju (Notice of Claim) zastarjelo zbog 28-dnevnog vremenskog ograničenja, ali se druga strana ne slaže sa tim, strana čije je ovo potraživanje, dužna je da uključi ove činjenice u detaljan zahtjev, te one trebaju biti uzete u obzir pri dogovoru/određivanju.

Podklauzula 21.1. Uspostava DAAB-a (Constitution of the DAAB) predviđa postojanje stalne Komisije za sprječavanje i rješavanje sporova (DAAB). Komisija se uspostavlja na početku ugovornog perioda i postoji tokom trajanja ugovornog perioda. Procedura donošenja odluke DAAB-a i neprovođenje iste od strane ugovarača propisana je u podklauzuli 21.4. Donošenje Odluka DAAB-a (Obtaining DAAB's Decision) i podklauzuli 21.7. Neispunjenje odluke DAAB-a (Failure to Comply with DAAB's Decision).

Nova podklauzula 3.7. Utvrđivanja (Agreement or Determination) koja zamjenjuje podklauzulu 3.5. detaljno opisuje ulogu Inženjera u postupanju sa potraživanjima strana i predstavlja detaljnu proceduru sa vremenskim ograničenjima.

Nova podklauzula 8.3. Program (Programme) je ažurirana dodatnim zahtjevima početnog programa, te svi izmijenjeni programi trebaju biti dostavljeni Inženjeru (u skladu sa Crvenom i Žutom knjigom iz 2017. godine) ili Investitoru (u skladu sa Srebrnom knjigom iz 2017.

godine) - npr. trebaju biti prikazani kritični put i bilo koje kretanje ili povezana aktivnost, ključni datumi isporuke za postrojenje i materijale, te svako odlaganje i vremenski slijed radova na otklanjanju nedostataka

## 5.2. Rokovi po FIDIC-u iz točke 20.1.

Kako je prethodno u radu navedeno osnovna promjena FIDIC-a iz 2017. godine u odnosu na raniji FIDIC 1999. je upravo po pitanju posljedica prekoračenja roka za predaju “notica” sukladno točki 20.1. FIDIC-a. Konkretno, sada se više ne bi moglo tumačiti da se naručitelj oslobađa obveze ukoliko izvođač prekorači rok od 28 dana za predaju Notica, već o tome odlučuje nadzorni inženjer u roku od 14 dana.

Ovo pitanje se često u praksi javlja kao sporno pitanje te je SAS pri HGK o ovome pitanju već prethodno zauzimao svoj stav u brojnim odlukama. Neki primjeri tih odluka su u predmetu AS-P-2011/68 gdje je arbitraža odbila zahtjev izvođača zbog propuštanja roka za stavljanje zahtjeva po osnovi povećanja cijene izvedenih radova u Izvještaju o završetku.

Jednako tako je i u odluci u predmetu AS-P-2012/22 zauzeo stav da je posljedica propuštanja davanja “obavijesti” u roku 28 dana - gubitak prava, a tako i u odluci AS-P-2015/8.

Unatoč ovakvim odlukama arbitraže, za spomenuti je da je sukladno odredbama našeg ZOO-a<sup>19</sup> propisano da su nišetne one odredbe općih uvjeta koje su suprotne načelu poštenja i savjesnosti i koje na taj način mogu prouzročiti neravnopravnost u pravima i obvezama suugovarača sastavljača općih uvjeta.

Također, odredbama ZOO-a propisano je da ako se neki ugovor sklapa „prema unaprijed otisnutom sadržaju ili kad je ugovor na neki način pripremila i predložila jedna ugovorna strana, nejasne odredbe tumačiti će se u korist druge strane“<sup>20</sup>. Ova odredba jasno propisuje da ona strana koja je pripremila i predložila tekst ugovora treba snositi i odgovornost za njegove nejasne odredbe. Odredbe ili termini nekog ugovora, pa tako i odredbe općih uvjeta koje su sastavni dio ugovora, koji je pripremila jedna strana, a koju nisu jasni i koji bi mogli prouzročiti štetu, protumačiti će se u prilog one strane koja nije predlagala ili nije sastavljala taj ugovor.

Međutim, kako je vidljivo iz prethodno navedene prakse, nije slučaj da se ovo pravilo primjenjuje i na tumačenje OU FIDIC kao općih uvjeta ugovora.

Neki autori tumače da je moguće razlog tome što kod OU FIDIC-a nije riječ o općim uvjetima koji su sastavljeni od strane jedne ugovorne strane, već ti OU nisu sastavljeni niti od jedne od ugovornih strana, već su sastavljeni s izričitom namjerom da u odnose između ugovornih strana unesu pravednu raspodjelu odgovornosti, pa da stoga sudovi niti neće postavljati pitanje njihove valjanosti na temelju navedenih odredbo ZOO-a o nišetnosti općih uvjeta.<sup>21</sup> Također, i Naručitelj koji primjenjuje opće uvjete FIDIC-a nije i njihov sastavljač. OU FIDIC sastavlja profesionalna međunarodna organizacija savjetodavnih inženjera putem svojih radnih tijela u kojima sudjeluju predstavnici naručitelja, izvođača i savjetodavnih inženjera

<sup>19</sup> Čl. 295. i 296. ZOO-a.

<sup>20</sup> Čl. 320. ZOO-a.

<sup>21</sup> Vukmir, B., op.cit. (bilj.17.), str. 13.

kojima je glavni cilj da u promet stave uvjete ugovora o građenju koji sadržavaju uravnoteženu raspodjelu prava i obveza svih sudionika u građenju.

Osim navedenog pitanja ništetnosti zbog dovođenja u nejednak položaj ugovornih strana, može se postaviti i pitanje ništetnosti pojedinih odredbo FIDIC-a, pa tako i odredbe o rokovima za podnošenje zahtjeva obzirom na njihovu protivnost „moralu društva“.

Stoga bi po prigovoru ugovorne strane o protivnosti određene odredbe moralu društva, sud morao ispitati opravdanost takve odredbe u okviru ugovora o građenju, te donijeti odluku je li takva odredba toliko neuobičajena u hrvatskom pravu da se može smatrati da je protivna „moralu društva“.

Primjerice kod odredbe čl. 20.2. OU FIDIC 2017. može se tumačiti da je ona opravdana jer je s jedne strane, takva odredba usmjerena na uredno vođenje administracije ugovora. Njome se prisiljava izvođače da sva svoja potraživanja i sve razloge za njihovu opravdanost iznesu na razmatranje nadzornom inženjeru odmah čim nastanu, a ne tek na kraju ugovora. S te je strane odredba opravdana. Međutim, s druge strane, može se postaviti pitanje je li zaista opravdano da zbog propuštanja tako kratkog roka izvođač ostane potpuno bez prava na svoje potraživanje. Svakako da je za potrebe upravljanja ugovornim odnosima takva odredba valjana i obvezuje izvođače sve dok nadležni sud ili arbitražna ne bi takvu odredbu iz nekog razloga proglasili ništetnom.

Dakle, kako je prethodno pojašnjeno moguće je polemizirati oko toga jesu li kratki rokovi i potpuni gubitak prava na neko potraživanje iz odredbe 20. OU FIDIC (i starog i novog) protivni prisilnim propisima hrvatskog prava, odnosno može li sud kod tumačenja njihove primjene utvrđivati njihovu ništetnost obzirom da ih se može smatrati suprotnim načelu savjesnosti i poštenja, te da uzrokuju očiglednu neravnopravnost u pravima i obvezama na štetu „suugovaratelja sastavljača“ ili „ugrožavaju postizanje svrhe sklopljenog ugovora“ kako to propisuju relevantne odredbe ZOO-a o ništetnosti općih uvjeta.

Konačan odgovor na pitanje je li potpuni gubitak prava na neko potraživanje koji je predviđen u OU FIDIC-u, samo zato što je propušten kratki rok za postavljanje i za specifikaciju zahtjeva (28 odnosno još 14 dana), u skladu s načelima hrvatskog obveznog prava kod ugovora o građenju će morati dati sudovi u svakom konkretnom slučaju.

S pravnog stajališta nema zapreke da ugovorne strane mijenjaju odredbe OU-a, pod uvjetom da to čine na način kako to predlaže FIDIC. Međutim, ako ugovorne strane nešto mijenjaju u UU FIDIC-u, tada trebaju biti pažljive da se ne poremeti čitav sustav podjele prava, obveza i rizika koji je ugrađen u te UU-e. Ponekad neke primjene u jednoj odredbi mogu utjecati na druge (povezane) odredbe i ako se ove ne prilagode izvršenoj promjeni, može se promašiti cilj koji se promjenama želio postići.<sup>22</sup>

OU FIDIC predviđa brojne slučajeve kod kojih Izvođač može tražiti produljenje rokova za izvršenje radova. Produljenja se razlikuju po tome koji su uzroci njihova nastanka te kakvo se pravo na naknadu priznaje. Kod nekih od tih slučajeva Izvođač ima pravo samo na produljenje

<sup>22</sup> Vukmir, B., op.cit. (bilj.17.), str. 14.

rokova (bez prava na naknadu troškova). Kod drugih slučajeva Izvođač ima pravo na produljenje rokova i na naknadu dodatnih troškova, dok se kod nekih slučajeva Izvođaču priznaje i pravo na produljenje rokova uz naknadu troškova i na naknadnu korist. U svakom slučaju prilikom podnošenja bilo zahtjeva za produženje roka, bilo zahtjeva za naknadu dodatnih troškova, izvođač mora postupiti u skladu s rokovima iz odredbe čl. 20. OU FIDIC.

Upravo ovi zahtjevi izvođača koje je nadzor odbio su najčešći predmet spora po FIDIC-u. Ne postoji analogna zakonska odredba za eventualni izvođačev zahtjev za nadoknadom troška, osim općih odredbi ZOO o zastari, te stajališta sudske prakse koje zauzima stav da je izdavanjem okončane situacije izvođač odustao od daljnjih zahtjeva koji su mu bili ili mogli biti poznati do izdavanja okončane situacije. Ovdje treba dodati okolnost da hrvatsko pravo ne poznaje niti prekluzivan rok za izdavanje okončane situacije.

Za spomenuti je npr. „žuti“ FIDIC koji u točki 20.1. daje definiciju gubitka prava za tzv. notice, ali ne i kod roka za tzv. claim, pri čemu nije moguće dati jednoznačan pravni stav, jesu li oba roka prekluzivna ili samo jedan ili ni jedan.

## 6. Zaključak

U praksi su penali upravo ono pravo koje naručitelj gotovo u pravilu konzumira ako ima ikakve uvjete na njega, dok s druge strane istovremeno u financijskom smislu korištenje tog prava u pravilu anulira dobit izvođača. Pri tome, ovdje je potrebno spomenuti da su protivne prisilnim propisima i moralu društva odredbe kojima jedna strana ekstra dobiva, a druga strana ekstra gubi, tj. kada nije riječ o primjerenim iznosima i omjerima. Navedeno proizlazi i iz općih načela obveznog prava koja daju odgovor što je u nekom ugovoru zakonito, a što nije. S time da su ta načela ponekada i međusobno suprotna kao primjerice načelo jednakosti davanja i načelo poštivanja ispunjenja obveza iz ugovora (*pacta sunt servanda*), što sve čini dodatno složenijim.

Pitanje penala se nerijetko površno pojednostavljuje i pokušava se tumačiti kao puki matematički izračun dana kašnjenja sa ugovorenim vrijednostima (postoci ili promili). Naravno da takav pristup nije dostatan i može samo uzrokovati vrlo skupe sporove.

U svakom slučaju korisno je primijetiti da su upravo one odredbe FIDIC-a koje uređuju postupanje izvođača povodom podnošenja svojih zahtjeva i daljnje odlučivanje o tim zahtjevima sada korigirane.

Problem „novih“ OU FIDIC je u tome što je Inženjeru povjerena određena diskrecijska ovlast prilikom donošenja važne odluke o roku, a riječ je o strani koja je u ovisnom položaju u odnosu na jednu ugovornu stranu i to na Naručitelja. Naime, Naručitelj je naručio Inženjera i platio mu da Inženjer brine o njegovim interesima, pa je stoga u startu upitna neovisnost Inženjera i objektivnost u odnosu na obje ugovorne strane, i Naručitelja i Izvođača.

Dodatno je potrebno naglasiti i da buduće odluke Inženjera u pogledu rokova moguće neće biti jednake kao kasnije eventualne odluke sudaca po istom pitanju, a sve obzirom da je legalno i legitimno da sudac ima suprotan stav od stava Inženjera. Time „novi“ OU FIDIC može dovesti u zabludu stranke koje doslovnim tumačenjem ovih odredbi OU FIDIC iz 20.1. mogu smatrati da je odluka Inženjera jedino ispravno i konačno rješenje.



Zbog navedenog moguće je i za očekivati novi broj sporova u vezi FIDIC-a, jer su veće ovlasti dane potencijalno pristranoj osobi.

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# **Building Information Modeling**

# BIM Implementation in Public Infrastructure: CDE Design for Italian Airport Systems

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## **Abstract:**

Introducing BIM into a company enables the benefits of technologies provided by the digital transformation. Furthermore, it requires a review of corporate information processes and the introduction of IT tools and systems that support them. Complex data distribution in different databases (for medium-large companies) generates lots of difficulties for the optimal definition of a Common Data Environment (CDE). This case study paper analyses the current state of art in worldwide BIM implementation for airports and presents an innovative approach developed in two Airports of the North Italy area. The existing studies focus on the impact of BIM implementation in a reference domain limited to BIM models, actors, flows, costs, benefits and Facility Management topics. Very few tackle the subject of Data Management. Therefore, the research project focused on the analysis and the development of a CDE able to communicate with the company information system, considering IT and Hardware infrastructure needs. The first step was the analysis of CDE structure as originally defined by British Standards 1192-1:2007 & PAS 1192-2:2013, identifying required software functions in the context of application. Secondly, a detailed analysis was conducted on commercial software and platforms, highlighting their alignment with the identified needs. The final output of this research is a theoretical framework for the CDE flow based on the British Standards and designed to meet the needs of the company that owns the airports and the proposal for a general structure of EIR (Employers Information Requirements) to provide guidelines for the use in tenders.

*Keywords: BIM implementation; airports; data management; CDE.*

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## **1. Introduction**

Introducing BIM into a company means benefiting from the technologies provided by the digital transformation and reviewing corporate information processes and flows. Full BIM implementation can take from 1 to 10 years and requires some essential activities and associated tasks (National Academies of Sciences, 2016):

- establish a BIM implementation team (team members, roles and responsibilities, consultants...);
- design BIM integrated processes (work and information flows...);
- document model and facility data information needs;
- determine infrastructure needs (software & hardware);
- develop an educational program and a training strategy.

Among all these points, the focus of this research is centered on how data and information are managed within the complex workflows of an airport structure. The effort of this study is to highlight the need for a review of company information processes and for the introduction of IT tools and systems that enable and support these processes. First of all, the data sharing environment (Common Data Environment - CDE) is of fundamental importance, representing the virtual place of collaboration of each actor, in every phase of the process, for the optimization of the information flow.

Thus, this case study paper analyses the current state of art and practice in worldwide BIM implementation for airports and presents an innovative approach developed for the CDE central topic in two airports of the North Italy area. The main goal of this research is to outline the state of the art especially regarding the implementation of company information systems in the airports where the BIM implementation took place, to understand if and how this issue was addressed in such a complicated process, and to provide useful guidelines for next cases.

The case studies considered are 10 airports in which the BIM implementation process took place or (as for most cases) is still ongoing. Currently, little guidance is available for airport operators on how to implement BIM from project conception through planning, design, construction, commissioning, operation, maintenance, and demolition, focusing on themes that range among BIM models, actors, flows, costs, benefits and Facility Management topics. Although several airports have utilized some BIM tools and processes in their development programs, there is a shortage of documentation on the topic of management of information flows within airports.

For this reason, the first step of this study was the analysis of CDE structure as originally defined by **British Standards 1192-1:2007 & PAS 1192-2:2013** and Italian **UNI (11337:2017)** identifying the optimal information flow and the required software functions in the context of application.

Then the focus has shifted to IT tools and systems that can fulfill the function of CDE. An assessment of the existing software structure was made in the airports of the case study. The research focused on the analysis and the development of a Common Data Environment (CDE) able to communicate with the company general information system, considering IT and Hardware infrastructure needs. After that, an analysis was conducted on market proposals for software and platforms, highlighting their alignment with the identified needs.

The final output of this research is a theoretical framework for the CDE flow based on the British Standards and designed to meet the needs of the company (resulting from the interviews with company members). Moreover, the research provides a proposal for a general structure of EIR (Employers Information Requirements) to be used as a guideline to set requirements about information management in tenders.

## **2. Research Methodology**

The research starts with the **literature review**, in order to highlight the main impacted processes during a BIM implementation process in airport structures.

Table 1. Overview of examined articles

Main topic of the article/regulatory	Number of articles/regulatory (n)	Percentage of the total (%)
BIM (general)	22	100
BIM implementation (general)	16	72,7
BIM implementation in airports	12	54,5

For this research, only the 12 articles focused on BIM implementation in airports have been considered and cited.

Table 2. Example cases airports in examined articles

Nationality of the 10 example case airports	Number of airports (n)	Number of articles (n)
Canada	1	1
USA	4	3
Germany	1	1
Italy	1	1
UK	1	2
Turkey	1	1
China	1	1

In the case study, the investigative approach is based on the analysis of the available **documentation** and the organization of **meetings with representatives of each division/function**, with the constant participation of information systems (in order to parallel the assessment of IT support systems). The resources interviewed are those most involved in different phases of the process and with heterogeneous skills and responsibilities, in order to obtain an overview of the organization of the various flows. The interviews were based mainly on the following topics:

- the potential of the used information systems with respect to possible implementation requests in BIM processes;
- the relationship among the used information system with the other systems and how data are distributed in the different systems;
- how the information system is able to keep track of the history of data uploads;
- the input data and the output data of the used information systems.

For the definition of the Software and Hardware essential for the implementation process, surveys were conducted through *Google trends*, a tool which allows you to know the frequency of research on the web of a given topic

### **3. Literature Review (State of art and practice)**

Articles have been collected regarding 10 airports, where the BIM implementation process is underway, at different stages of implementation maturity.

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*Background of the example cases*

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- **A Canadian Airport (Canada)**

The business managing firm of this Canadian airport decided to implement BIM in 2013, using the construction of a new terminal as the “pilot project” for the implementation process (Boton and Forgues, 2018);

- **Istanbul Grand Airport (Turkey)**

In IGA project (started in 2013), BIM was employed at all of the project phases, playing a crucial role to expedite the development process (Koseoglu, Sakin and Arayici, 2018);

- **Chongqing Jiangbei International Airport (China)**

This airport started implementing BIM during the project for the T3A&B terminals. The BIM team was appointed by the contactor in middle of the construction (A. Badrinath, Y. Chang, E. Lin, S. Hsieh, 2016);

- **Denver International Airport (USA)**

DIA started implementing BIM in 2010 defining an overall airport BIM plan, then used the “*Hotel and Transit center*” project as the pilot project and finally moved to implement BIM for use in the day-to-day asset management of the entire airport facility. Now it’s realizing benefits of full BIM Implementation (Ball, 2013) (National Academies of Sciences, 2016);

- **Gatwick Airport (UK)**

It is the UK’s second largest airport. BIM was introduced in 2009, BIM Standard have been adopted from 2012 but still there are some processes to convert into a BIM frame (Jameson and Richardson, 2013) (*The Gatwick Airport BIM Journey*, 2017);

- **Pisa’s “Galileo Galilei” International Airport (Italy)**

It adopted BIM as methodology of Project Management to apply Lean Construction principles (Bosi and Esposito, 2013);

- **Berlin Airport of Tempelhof (Germany)**

The airport developed its BIM Model of its facility with the model use of Event Management, at the case of a public event, ‘Sommerfest – Tag der offenen Tür’, organized in September 2018 (Besenyői, Kramer and Husain, 2018);

- **Massachusetts Port Authority (Massport) - Boston Logan International Airport (USA)**

BIM and Lean principles are equally essential enablers in MPA’s strategy for innovative project delivery and lifecycle asset management. MPA expects BIM to be used within a Lean environment conducive to information flow, communication, analysis, and problem solving (National Academies of Sciences, 2016) (Sleiman and Burdi, 2001);

- **Los Angeles World Airports (USA)**

LAWA is realizing benefits of Project-Level BIM implementation. They noted that main benefits are related to enhancing construction and building performance through better information. Specifically, BIM use helps this airport to mitigate the negative impact on efficiency (e.g., schedule and cost) and risk (National Academies of Sciences, 2016);

- **San Francisco Airport Commission (USA)**

The initial goal of its BIM Implementation Program was to have the verified, virtual representation of the airport’s infrastructures, which will be used to support all airport operations, especially in facilities maintenance. The airport is now approaching a new full BIM implementation (National Academies of Sciences, 2016).

### *Reference domain of the impacted processes*

Both considering the issues addressed in the various airport example cases and in other examined articles focused on BIM, the following macro-themes have been identified, with respect to which critical issues and possible solutions have been highlighted.

### *BIM models: Guidelines and coordination*

From a practical point of view, in a BIM implementation process it emerges the need for guidelines and standards for interdisciplinary coordination and information sharing. The first critical issue is linked to **the existing data sources**: the main difficulty is in identifying the most accurate files of the project, spread out in various disks, drives and file cabinets. BIM implementation first benefit is to led the project to a model-based approach where the model is updated continuously and becomes **the central point of truth**.

For huge and complex airports projects, **guidelines and standards for interdisciplinary coordination** and **information sharing** are essential topic for the project success in each phase. It becomes necessary to develop a **BIM Implementation Plan** and then a **BIM Guide** for the company, containing industry data standards, new process changes and emerging technologies.

Other innovative solutions for improved coordination and collaboration proposed in some example cases are:

- the use of a common physical space, usually called “**BIM Room**”, that can be used both as workspace (near the construction site) and as a space for daily or weekly meetings. In both cases, it has very positive impact on interdisciplinary coordination and collaboration processes thanks to the improved communication among team members and other stakeholders.
- cloud based software for **collaborative model review**.

However, despite the solutions adopted to provide useful guidelines, there still be some not solved issues.

Please see: (Sleiman and Burdi, 2001) (Amuda-Yusuf, 2018) (National Academies of Sciences, 2016) (Ball, 2013) (Boton and Forgues, 2018) (A. Badrinath, Y. Chang, E. Lin, S. Hsieh, 2016);

### *Facility Management*

After developing its strategy to execute BIM on projects and in its operations, an organization begins the process of acquiring and implementing BIM throughout the facility life cycle. This will support its organizational goals of managing assets in ways that maximize facility life-cycle value and minimize the true cost of ownership.

From building operation and FM perspective, the BIM Model is the **digital twin** of the existing building. It serves as a single source of truth, providing continuously up-dated building-related information in order to support different FM-related application scenarios. Despite of these benefits, BIM for FM is still an emerging area and there is still limited knowledge available on the subject. One of main issues is linked to the need to **adapt design/construction models** to make them useful for the operating phase. *Denver International Airport* is the only respondent airport that has a comprehensive FM program in place. It currently uses BIM for space management/tracking, asset management, and maintenance scheduling.

As regards the information transfer, **COBie** (*Construction Operations Building information exchange*) is an exchange format created to facilitate data transfer from BIM to FM systems. The critical issue is its low adoption: even if it has been incorporated into more than 20 different BIM software packages and tools, it is still not well understood by facility owners.

Please see: (National Academies of Sciences, 2016) (Ball, 2013) (Kim, 2018) (Besenyői, Kramer and Husain, 2018).

### *BIM actors*

A clear definition of the BIM roles and responsibilities within a facility owner’s organization is essential if the owner is seeking BIM for operations and asset management. Critical to the organization’s BIM implementation is a **BIM champion**, along with key personnel including BIM manager, BIM specialist and technology specialist. They should have the requisite skills and knowledge in design, construction, and operations roles. A critical issue is the possible crystallization of the information sub-process around the BIM managers: it reveals how it is necessary to clearly redefine the connections and the interactions between the workflow and the information flow and, as a consequence, the need for information



management guidelines. This generates a new hypothesis to investigate: the definition of a **CDE** for information sharing.

Please see: (National Academies of Sciences, 2016) (Boton and Forgues, 2018).

### *BIM flows*

A common approach in the studied airport cases is based on the synergies between Lean Construction and BIM, with the purpose to have lean project flows. *Pisa's Galileo Galilei airport* adopted the following innovative strategies:

- **project information sharing** with computer tools: the activities that don't generate "value" for the project are limited, avoiding the waste of resources for the Design Team and delays in the project process due to redundant activities;
- a phase of **self-control** to reduce the time of validation allowing a designer to perform individually a control of the produced material.

Please see: (Bosi and Esposito, 2013) (Bosi et al., 2016).

### *BIM costs and benefits*

BIM implementation process can be very expensive for a corporation, but the truth is that benefits are huge, in the long term, especially in terms of reduction of time and cost wasted.

Significant benefits can already be registered by the **design and the construction phases**. Some airports assumed that with the introduction of BIM in the earlier design stage, the design coordination achieved by BIM tools can significantly reduce the amount of hours spent and design clashes detected. Several airports tried to improve coordination and quality control in the **construction phase**, by electronic file sharing on iPads with collaboration platforms: the main advantage is the reduction of paper on site and the real-time progress control, monitoring and timely communication of the QCs and control on site.

Anyway, **the best ROI (Return Of Investment) is linked to the 6D - AIM (Asset information Management)**. Obviously, to achieve this goal, an efficient management of information and data is needed since the earliest phases of the project. Nowadays, none of the articles examined deals with the subject of information management in depth.

Please see: (Jameson and Richardson, 2013) (Shaaban and Nadeem, 2015) (Azhar et al., 2008).

### *DATA management*

As regards data management, the main goals in a BIM Implementation process are:

- collect all relevant information the first time and avoid redundancy and duplication of data;
- exchange data in the most structured electronic form;
- integrate data entry and data maintenance tasks into the organization's business processes;

- adopt open standards;
- determine infrastructure needs (software and hardware): ensure sufficient computer software proficiency and ensure sufficient database management capabilities.

Among all the common barriers attributed to BIM adoption, most of the studied airports identify the **lack of data-storage capacities** in their traditional workflows. They generically refer to cloud-based data management, naming tools and software used, but they never enter into the specific flows within these information management systems.

In order to improve the data asset management, *Denver International Airport* is replacing its recent platform with a newer software tool. It provides a direct link between BIM and CMMS (Computerized Maintenance Management System) that permits a bilateral exchange of information and also allows flexibility. However, DIA determined that developing and maintaining this entirely custom system would be **cost prohibitive**, thus its organization's Computerized Maintenance Management System (CMMS) and its organization's asset management system aren't integrated with BIM software for data exchange yet.

Before BIM implementation, *Gatwick Airport* was using *IBM MAXIMO 5.2*. There were critical issues: minimal metadata inclusion, FTP and email being used as uncontrolled document transfer, limited change control for updating archive data, data not linked directly to models, too much time taken to receive and to input data. Thus, they identified the need to address these issues to improve synergy with their Asset Stewardship Procedures.

Most of the studies reveals the need for a **“Project Requirement” document** that describes asset data and information flows. *Massport* tried to fulfill this purpose with the BIM Roadmap and the BIM Guide, where it describes Document BIM Protocols for Model Review, Sharing, Access and Handover. *Los Angeles World Airports (LAWA)* has specified in its contract language the way that it expects information to be made available at the end of the project (closeout data delivery requirements). Additionally, LAWA requires the information to be consolidated into the record models and to be verified during the commissioning process, enhancing the accuracy of the information. However, in both cases, there is not a specific explanation about the CDE structure.

Please see: (National Academies of Sciences, 2016) (Jameson and Richardson, 2013) (The Gatwick Airport BIM Journey, 2017) (Kim, Yun and Cho, 2015) (Ball, 2013) (Koseoglu, Sakin and Arayici, 2018) (Sleiman and Burdi, 2001).

#### *The case study: CDE Design For Italian Airport Systems*

The research project is based on two airports in the North Italy area, whose company has decided in 2018 to implement BIM for the construction of new works and renovations planned in the development plan of the two airports. The aim of the research was to provide the company with guidelines for the management of company information flows, providing new BIM tools to be integrated into the existing structure.

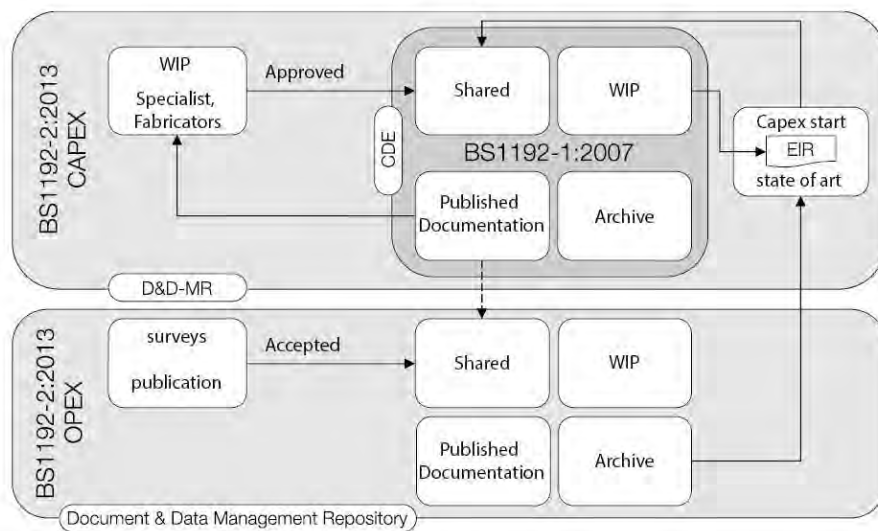
#### *Assessment of impacted processes*

The first step of this research in the examined company is the analysis of the processes impacted by the introduction of BIM and the mapping of the workflows of what appears to be the most impacted process. The most impacted process in this initial phase is the **Infrastructures Department**. The interviews showed that a rigid definition of the workflow response patterns is not possible, so the focus shifted to how **communications** occur within workflows: it is a non-formalized communication and structured, which takes place through standard channels (e-mail, dialogue, etc.) which generates the risk of loss of information. The introduction of BIM approaches in the company requires **clarity of information flows** in order to be able to fully adopt and exploit IT solutions available today at reasonable costs: it is therefore necessary to formalize the processes and information and authorization flows with the respective reference documents.

*Structure of a BIM oriented Common Data Environment (CDE/ACDat)*

The digitalization of construction processes contemplates the use of an environment for sharing data, information and information content (models and digital elaborates) where every actor, in every phase (strategy, project, production and operation), can interact with the others for the purpose of optimizing the entire information flow.

This environment was originally theorized by the **British Standard (BS)** in the voluntary standard **BS 1192-1:2007**, under the name of **Common Data Environment (CDE)** and in the subsequent Technical Specification of the British Standard: **PAS 1192-2:2013**.



**Figure 17.** CDE scheme defined in BS 1192-2:2013, digital and process extension, operational phase.

In the Italian regulatory scenario reference is made to the CDE (or ACDat) of **UNI (11337-1:2017)**.

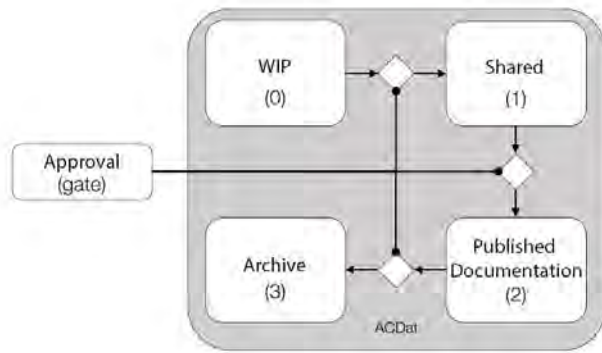


Figure 18. ACData sub-division in 4 environments of information evolution

Italian UNI places the CDE preferably **in charge of the client** and introduces the function of "CDE Management" and the role of "CDE Manager". The **CDE management rules** are specifically to be defined in the **Employers Information Requirements - EIR** (or **Capitolato Informativo - CI**).

#### *Software systems for data sharing CDE/ACData*

For this research, an analysis has been conducted on commercial software and information systems/platform, that can fulfill the function of CDE according to British Standards principles. A critical issue has been detected: they're **IT platforms for project collaboration**, which may eventually be organized as real CDE according to British standards. **None of them result to be structured in native mode according to the Anglo-Saxon principles**, although some flexibility is guaranteed to the user and, therefore, an effective full correspondence to the indications of the PAS 1192-2:2013. The analysis carried out on the main IT platforms on the market is shown below.

#### International platforms:

- BIM 360 docs
- Project Wise
- BIM Plus
- BIM X
- Trimble Connect
- Aconex
- Asite
- View Point
- Blue Cielo

#### Italian platforms:

- usBIM
- Vision Team-work Suite CDE

In most of the software analyzed the following features have been identified.

They are **IT platforms, software or coordinated software systems, cloud-based or installable on local servers**, useful for managing project documentation from the design phase up to the facility management. All files are published in a **single environment**, allowing all participants of the contract team to communicate, view, annotate and review work files, from anywhere and at any time. Most of them are in fact also usable by **mobile devices**. They are able to manage files and documents in different **formats**: BIM authoring files in native format (RVT...) or open formats (IFC, BCF...), and many other file formats (PDF, DOCX, DWG, DWF...). They are equipped with **internal viewers**, which allow you to view and, in some cases, interrogate the model. Some of them are also useful for **interdisciplinary coordination**, integrating files of different disciplines coming from different software (thanks to the open formats) and allowing to perform clash detection. They are often integrated with other software with features that enable processing of take-off quantities, Gantt charts, site management, augmented reality, etc. The administrator of the work team, through appropriate management of **permissions**, can assign to different users the ability to view, comment and/or modify certain files or documents within the shared project, through the assignment of specific roles and responsibilities. You can insert **comments and annotations** on files, revision **reports, #tag** to make it easier to search. In some case you can insert hyperlinks or attach documents to model elements (*usBIM*). Some of them provide **internal messaging systems** for operators. The **workflow** is set to define the steps of the work processes and the relative times, thus implementing the processes. Documents are, in some cases, subject to **approval** by the manager. The system therefore allows managing the document approval cycle. In some of them (e.g. *BIM 360 DOC*) a **notification** is sent to all managers every time a document is uploaded or modified. It is also guarantee the **traceability** of the changes that have occurred since in many cases there is a history of the activities and of the versions of the models/elaborates.

#### *CDE use in calls for tenders*

In recent years, there has been an increase in public and private tenders that involve the use of BIM tools and methodologies that are oriented in procurement, above all in design or construction, in some cases requiring the supply of real EIRs. In the more structured calls, the combination of a generic Data Base with a real CDE is usually required. For an airport structure, such as those of the Italian company being studied, among the different uses of the CDE the one for the tenders is certainly the most relevant, since almost all the activities related to a work are entrusted to external subjects. In this context, however, there are multiple critical issues:

- construction and management of the CDEs delegated to the assignees, therefore lack of a CDE of the commission relating to the work regardless of the contracts;
- coexistence of several distinct CDEs within the same process (one for each phase) with different architectures;
- request for unlimited control of the CDE (of the assignee) by the client;
- request to work directly in the CDE by the carers even during processing;
- lack (in the EIR) of defined rules for the construction of the CDE outsourced and the correlation of the data.

The only requirement, which is repeated in every announcement, is the use of **open formats** (especially IFC for graphic models) or **proprietary formats** (for the other works). In particular, having detected the absolute current lack of BIM management and maintenance contracts, for the design and construction stages it is possible to define the following flow structures being consolidated. Information flow consists of a flow of structured data exchange that takes place between individual CDE (internal) towards the only CDE of the work (by the client) and from this to its asset platform.

The current state of art reveals a prevalence of **emergency operations**, triggered in the absence of fully applicable organic rules of a long-term vision of the problem, especially in public procurement. This research, according to Italian UNI 11337:2017, attempts to respond to the critical issues that emerged with respect to the first approaches concluded:

- loss of control and knowledge of data in the construction and management of CDE delegated to the careers;
- lack of sound information and IT rules for the construction of CDE and data correlation;
- useless redundancy and sharing of unconsolidated data in the absence of new and specific contractual forms that are actually collaborative and not antagonistic;
- generation of hidden costs that are not adequately estimated;
- lack of organic data management for multiple assets and for each stage of the processes.

A CDE scheme for the case study (according to UNI 11337-5:2017) represents the idea of a unique environment for the entire process, from the strategic to the operational phase.

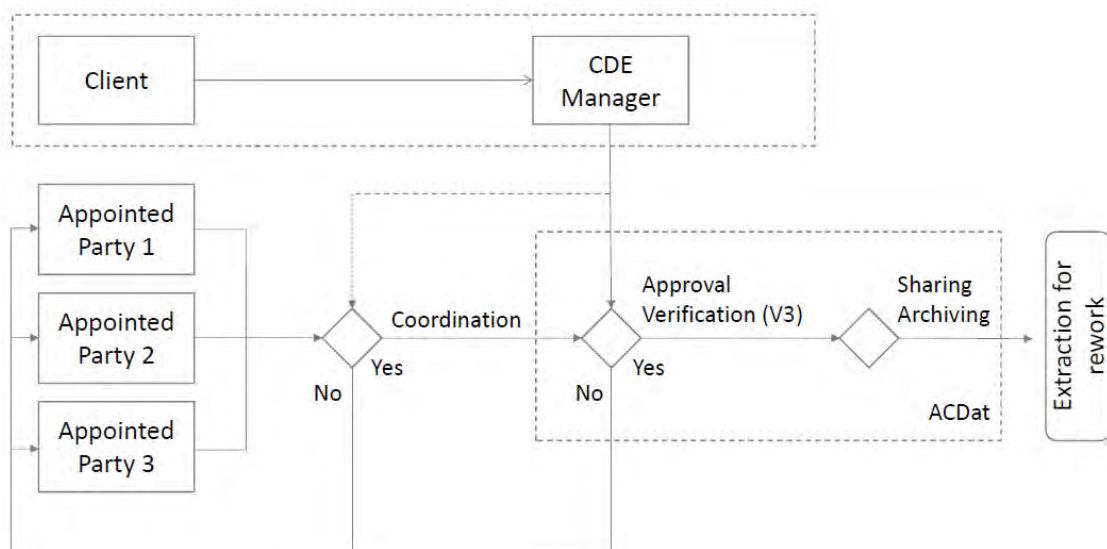
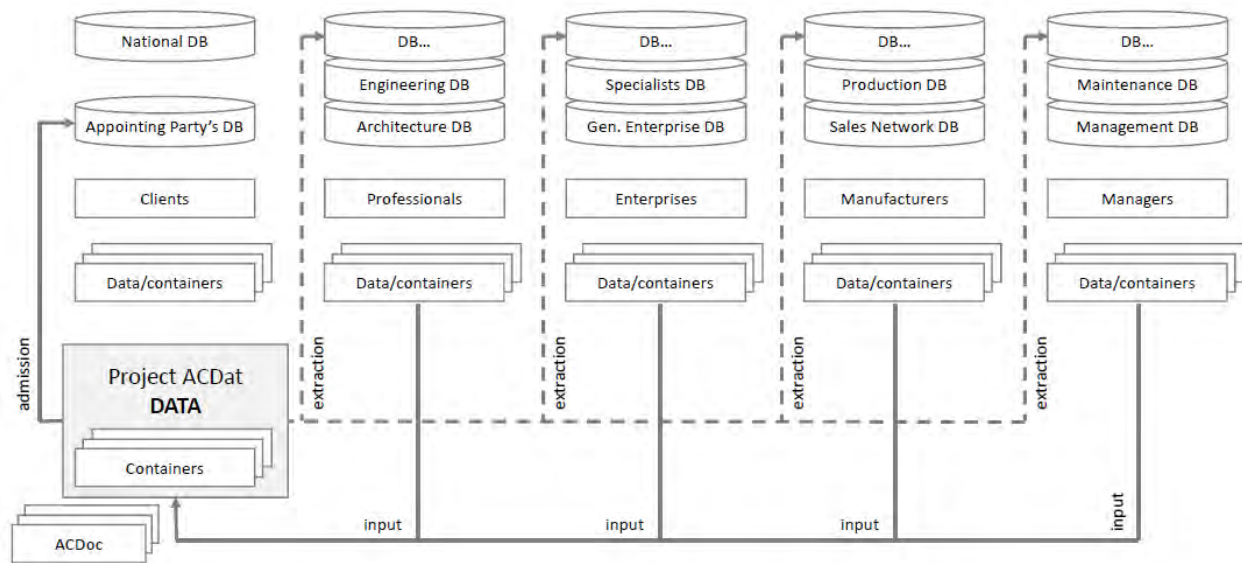


Figure 19. ACDat scheme (according UNI 11337-5:2017)

A structure of flows closer to UNI 11337:2017, consistent with the needs of the client and the purposes of efficient and effective data management, can be represented as follows.



**Figure 20. ACDat according to UNI 1137-5:2017**

In the current state of the contracts, the **data flows need consolidation**, suggesting that they be dealt with in CDE defined for the assignees (**Appointed Party's CDE**) and for the client (**CDE of the Work**).

With regard to the definition of the two aforementioned CDEs, in the Italian scenario a change of course has recently been recorded. Until a year ago, in relation to a specific work, a certain freedom was guaranteed to the contracting companies in the choice of the platforms or software for the definition of the CDE. At present it seems that, increasingly, the various stakeholders of the work (design studios, construction company, etc.) are required a certain flexibility, in adapting the definition of their CDEs to the choices (in terms of software and structure) carried out by the client.

### *CDE of the company*

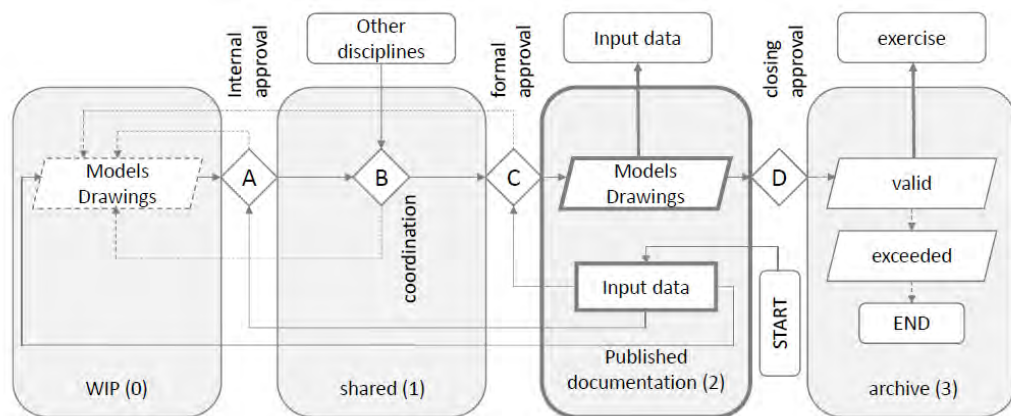
In the studied case, the structure of data coordination systems (collection, processing, exchange) can take the following scheme:

- CDE of a specific work of its real estate assets, subject to specific interventions (**Development CDE**) and/or maintenance over time (**Exercise CDE**);
- **libraries** of digital objects: owners or commercial;
- **paper project data rooms** and their transformation into **digital archives**, in open PDF format and questionable metadata;
- **IT Platform**, centralization of data in business management systems (EERP, etc.);
- **additional CDE of third parties**, interacting with internal ones (data entry and extraction), such as: subjects entrusted with works and / or services, suppliers of works or services, and in the future also authorizing bodies, etc.

## Development CDE of the company

In particular, the Infrastructure Management CDE (Development CDE) may have **three stages** of process development:

1. **Strategy CDE (stage):** analysis of the start-up requirements of the contract; recovery of the relief and information on the state of fact from the Maintenance Sector (Exercise CDE) and all the other information useful for the strategic phase;
2. **Project CDE (stage):** acquisition of the information from the Strategy CDE; preparation of tender models and documents for design services; performance of tenders and assignments, technical verification of offers; exchange of information with the designers (eventual CDE of the design team); publication of models and project drawings;
3. **Execution CDE (stage):** acquisition of the information from the Project CDE; preparation of technical attachments to the call for tenders for works; performance of tenders and assignments, technical verification of offers; management of information related to the execution of the works and to the as-built.



**Figure 21. Development CDE for the Infrastructures Department**

### Workflows

- Published documentation = Start

Publication of input data from an external or previous process.

- Work in progress

The disciplines involved pick up data of interest to them and treat them concurrently in the processing environment.

- [gate A: Internal Approval] → Shared → [gate B: Coordination]

The models and the elaborates in process, having reached a defined maturity, are examined by the respective disciplinary leaders (*gate A*) which establish the completeness and congruence respect to the input data as well as the need for coordination with other disciplines. In case of incompleteness or inconsistency, the disciplinary leader sends back to work the model not



approved or approved with comment. Shared models and elaborates are coordinated with the other disciplines (*gate B*). In the event of interference or inconsistencies, the models return to work for the necessary modifications.

NOTE: during processing some models, even if not internally approved, could still be shared and coordinated in advance in order to speed up some operations and avoid subsequent interference in more advanced phases.

- [gate C: Formal Approval] → Published documentation

Coordinated models and documents can therefore be brought to the *formal approval* by a subject with the necessary authorities also to subjects outside the company, always with simultaneous verification of completeness and congruence with respect to the original input data. If not, the models not approved or approved with comments are back in process for the necessary modifications. The coordinated and approved models are published for availability to third parties, other disciplines, approval bodies, etc.

- [gate D: Closing Approval] → Archive

The data being published may go on to the next process step and to the next CDE status or be defined as completed and archived (*gate D*). In the archive environment, the data remains "valid" until it is transferred to the Exercise CDE. Passage of state that will determine the condition of exceeded in the development archive.

### **CDE for tender management and deposit**

A specific requirement of the CDE is to host and manage the material produced by third parties both as a storage environment and as a verification and acceptance environment for the deposited material, in addition to data entered by the CDE Manager. The CDE will have different uses and flows depending on whether it is the "tender" phase or the subsequent real phase of the service or contracted work.

### **CDE needs and functionality**

In order to identify an IT application suitable to support the various activities assigned to an instrument such as CDE, as identified in the previous chapters, an analysis has been conducted on the main **needs and functionalities to be met** by the system that will be adopted. Some of the investigated functions are the management of data, files and workflows, the visualization of 3D models, etc.

As result, any commercial solution currently available will require additional software development to complete its efficiency and personalize its effectiveness with respect to the company's specific needs, as well as integration with existing systems the new environment will have to interact with.

#### *Assessment of existing software structure*

An analysis has been conducted on the functionalities of the software used by the company and their possible future developments and improvements, to verify if they are able to support

the definition of a data sharing environment or if it is necessary to support the same tools with new collaborative and information management environments as required by the structuring of the processes in a BIM logic.

The analysis reveals that, at present, the analysed systems are therefore not able to respond autonomously to the requests of a common data environment. Thus, there is the need to introduce one or more separate environments able to guarantee the characteristics of collaboration and dynamism typical of the design and construction activities to be then integrated with the existing systems in well-defined moments (Milestone).

It has also been found that in complex realities, such as airports, there are often numerous software that perform the same functions, thus generating an overlap of tools to manage the same operations.

#### *Hardware and software requirements*

In order to support the BIM methodology, it is necessary to make sure that you have the right technology, in terms of software and hardware, that allows an efficient and effective use. First of all, there is the decision between single Workstations or Server. This initial difference must be understood and managed with particular regard to the context in which the company works. Probably the best solution is to go towards a **server** solution, which has the advantage of directing the high computing power to the specific request. However, it is first necessary to identify the software to be installed and test them on a physical workstation, and then install them on a server.

The collaborative platform not yet on the market *UsBIM.platform (ACCA)*, in association with the *UsBIM.browser* plug-in, will allow to manage the models in a single data sharing environment, visually navigable from the internet, as well as the project sharing software *BIM360 Autodesk Team*, where you can share and view the different files and annotations of the different design teams, even outside of *Revit*. *Primus.platform (ACCA)* is an electronic communication cloud platform for the job journal useful during the construction phase. In this phase.

The Autodesk proposal for the construction phase includes different software:

- *BIM 360 Field* tracks, in a single centralized environment, the management of the teams, the progress of the works, any problems and solutions adopted, useful both during the construction phase and the delivery phase;
- *BIM 360 Docs*, for coordination from planning to delivery;
- *BIM360 Glue*, for the execution phase.

#### *Employers Information Requirements: general structure*

The introduction of BIM requires the definition of new contractual documents that allow the client to clearly express their needs in terms of information and consequently guide the supplier in the development of the related activities.

In the British regulatory system (BS-PAS 1192-2:2013), the following are identified:

- **Employer Information Requirements (EIR):** pre-tender document containing the information to be provided and the rules and processes to be adopted by the supplier as part of the project delivery process;
- **BIM Execution Plan (BEP):** "plan prepared by the supplier to explain how the modeling aspects of project information will be implemented";
- **BEP pre contract** of the tenderer, during the awarding phase: the supplier's response to the requests made explicit by the client in the EIR;
- **BEP post contract** of the contractor, post award: consolidation of this proposal following the signing of the contract).

The **Italian context** is aligned with the British vision. The Italian standard UNI 11337-5:2017 identifies:

- Capitolato Informativo (CI): corresponding EIR;
- offerta per la Gestione Informativa (oGI): corresponding Pre Contract BEP;
- piano per la Gestione Informativa (pGI): corresponding Post Contract BEP.

### **Proposal for a generic EIR: assignment**

The structure of a "typical" EIR for the company of the airports in question is proposed below. The structure follows the general indications of the UNI 11337-5 and 6:2017 standard. Particular reference will be made only to the items related to **the management of data and information**, the central theme of this research.

The proposed scheme, of a general nature, can be applied to any other type of assignment, from design to management, with the appropriate modifications and specific additions.

#### Technical section

All the digital works and the models made available by the Contracting Authority will be provided in open format (mainly in pdf, rtf, IFC, xml format). Possible paper copies of the same, where possible extraction, will be available:

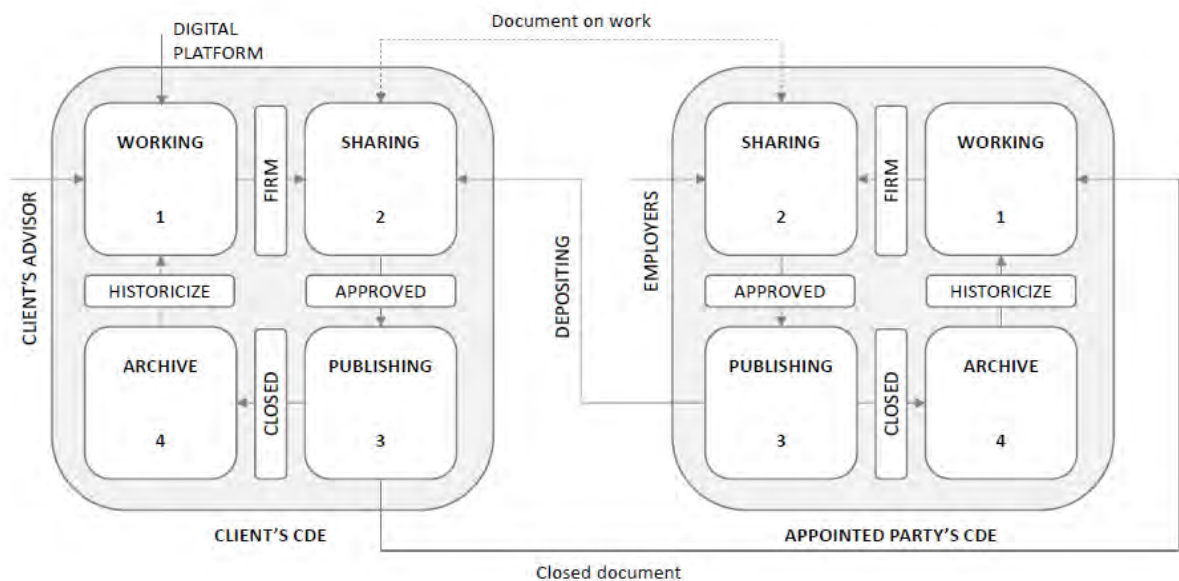
- for viewing, in the ACDoc of the Contracting Authority;
- for collection, upon request and payment of the living costs of reproduction and of the rights, at: [address]

All the digital works and the models produced by the Contracting Authority will be provided in open format (pdf, rtf, IFC, xml) and made available to the Assignee in the "Publication" space of the general CDE of the Call. In any case, the contractual prevalence of the paper copy (or digital in PDF format with digital signature) of the aforementioned documents or of the drawings/views of the models is not affected.

For the purposes of data exchange and filing the files must be provided to the Contracting Authority in the open format and, where specified, in the required open format. In the event of a dispute, the Contracting Authority may request the production of the original files in native format. In the cases of CDE requested by the Assignee, for the purpose of guaranteeing the reading, management and retention of data over time, the Affiliate himself, at the end of the

Call, must provide a specific report on the architecture, language, structure, etc. of the DB used on which the CDE is built.

For the purposes of efficiency in the sharing of data, information and information content (models and documents), their status of definition and approval must always be identifiable according to UNI 11337-4:2017. The Contractor is required to specify in his oGI (Pre Contract BEP), and consequently in the final pGI (Post Contract BEP), how he intends to satisfy this request. The Contracting Authority's ACDat/CDE and that of the Assignee must be divided into at least 4 sections useful for the distribution of data, information and information content of the Contract according to the definition status.



**Figure 22.** Information flow between internal ACDat/CDEs (by employers) and the CDE of the work (by the client)

The information flow between the different sections inside an ACDat/CDE must be defined by means of a progressive state act of passage (gate, gate). The information flow between the Contracting Authority's ACDat/CDE and that of the Assignee is through **regulated access** between some of the sections in which they are subdivided.

In the oGI, and consequently in the conclusive pGI, must be defined:

- roles, access rules, rights for ACDat/CDE.
- solutions for security (of data contained therein) and for traceability of the operations carried out;
- rules for files naming;
- method of programming and managing the information contents of any sub-contractors (responsibility of the successful bidder).

Once the Contract has been completed, each model or form contained in the Contracting Authority's ACDat/CDE will be transferred from the "published" section to the "archive" section. Each model or elaborate is considered deposited, in a digital sense, at the time of

loading in its open format in the "shared" section of the Contracting Authority's ACDat/CDE. At the time of loading the protocol is recorded with date, time and subject responsible for the upload. The validity and usability towards third parties also takes place from the date of publication (transfer to the "published" section). At the time of loading, the files that need digital signature will be indicated.

#### **4. Discussion and conclusions**

Airports are complex, constantly evolving realities which, together with the AEC sector, are more and more entering the BIM world. The biggest challenge of working with airports on BIM-supported projects is that they are generally not structured in a way that is conducive to BIM. Commonly, there is limited cooperation between departments or there is resistance to expanding the IT infrastructure needed to support BIM. The main challenges are related to system complexity, implementation duration, silos of information and general lack of guidance for airports. The complexity and the strength of BIM reside in making different and independent systems interact with each other, from both design and operational points of view. Since a "System of systems" model is defined, to whom several actors can refer within a complex airport structure, operational benefits will be substantial. But obviously a lot of improvement are needed.

Considering the little guidance nowadays available for airport operators on how to manage the corporate information system during a BIM implementation process, this research aims to propose innovative solutions by providing useful guidelines and tools regarding the information management to fulfill this purpose.

The final output of this research is a theoretical framework for the CDE flow based on the British Standards and designed to meet the needs of the company (resulting from the interviews with company members). Moreover, the research provides a proposal for a general structure of EIR (Employers Information Requirements) to be used as a guideline to set requirements about information management in tenders.

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# Active BIM: Review of Accomplishments, Challenges and Potentials

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## Abstract:

Building information modeling (BIM) is an intelligent multi-dimensional model-based approach that gives architects, engineers, and construction experts the tools to more efficiently plan, design, build and manage buildings. Such concept of BIM is commonly known as the passive BIM. However, when efficiency of building alternatives are required to be evaluated during the design- or the construction-phase, the passive BIM approach may not be sufficient. Dynamic systems, which connect BIM with analytical functions or solution techniques like optimization methods, represent a rather new concept of active BIM. The basic aim of this paper is to review accomplishments, challenges and potentials in this rapidly developing area as well as to expose gaps in literature including opening possibilities for further research. The paper ends with some conclusions and recommendations.

*Keywords: building information modelling; BIM; active BIM; optimization.*

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## 1. Introduction

BIM, as a developing concept, offers a spectrum of valuable features for construction project management. One of them is ensuring continuity of quantitative analyses of input parameters, their modelling and quantitative confirmation of feasible outcomes throughout project's life-cycle. In this context, BIM may provide input parameters, while optimization techniques can resolve their analyses, modelling and filter. Combining those in a dynamic two-way information stream, a modelling environment, known as active BIM, is structured.

Active BIM is a developing topic and an approach. Even though it seems that it simply covers the compatibility of BIM and optimization tools (i.e. software packages), it is far more than that. Active BIM is a dynamic concept of two-way data enrichment by connecting the two concepts. The importance of further development of active BIM lays in the fact that most authors overlook the logical connection of the two approaches. Even a recent international standard (ISO19650-1:2018), dealing with organization and digitization of information about buildings and civil engineering works, including BIM and Information management using BIM, overlooks the phase of input parameters optimization needed for planning, modeling and finally execution those works. In this perspective, the well-known fact that the quality of output depends on the quality of input perhaps gives the sense about the necessity of using the approach addressed here.

This paper introduces origins of active BIM, its features and relations with passive as well as baseline BIM. The motivation of this study is to summarize recently presented



accomplishments, challenges and potentials of active BIM. The remainder of this article is structured as follows. Section 2 is intended to show metamorphosis of BIM into active BIM. Methodology of the review is introduced in Section 3, which is thereupon followed in Section 4 by the overview of applications of active BIM. Section 5 gives brief discussion about dealt topic and provides some conclusions at the end of the paper.

## 2. Metamorphosis of BIM into active BIM

A recent paper (Tang *et al.*, 2019) summarized the body of knowledge of 97 recent BIM-related papers published in relevant journals. The said paper presented a review of BIM's current development trend and its integration with real-time data from the Internet of Things (IoT). In conclusion, authors underlined the inevitability of AEC's "pervasive digital revolution", whilst one of five-pointed directions is the enhancement of BIM into a two-way dynamic interaction system of information acquisition and control. While BIM leans toward server-operated, open-folded and highly visual construction modeling, optimization techniques are considered highly mathematically oriented. As often, the results of those techniques have to be interpreted separately, because they tend to be difficult to understand for most project stakeholders. Hence, optimization techniques, due to their characteristics, are usually kept as black and grey boxes in construction project decision-making processes. As a response to new developments, logical connections between BIM and optimization approaches are defined in literature as enriched BIM dynamic systems, or by the term "active BIM".

Active BIM, as an enriched BIM system supported with additional decision-making functions intended to provide active solutions, was reported by Moon *et al.*, 2013, while Kim *et al.*, 2014 stated that "*active BIM functions visually comprehend a problematic situation, and use methodology to present the improved situation*". While discussing potentials of cloud-BIM technology, Wu and Issa, 2012 have stressed the importance of active BIM server enabling a bidirectional connection to the live BIM model to projects stakeholders. Active BIM environment, although in this case referred as an active nD CAD, was structured by Kang *et al.*, 2016 for the purpose of managing construction schedule by telepresence, whilst acknowledging that the main idea, of active BIM as a dynamic system utilizing optimization algorithms, was presented by same authors in previous papers (Kang *et al.*, 2012; Kang *et al.*, 2015). Same authors (Kang *et al.*, 2013) presented a graphical metamorphosis of "passive BIM" into "active BIM" (shown in Figure 1), where BIM's initial features of 4D/5D/6D modeling (i.e. "passive BIM") was expanded by analysis and optimization of construction risks, resources, costs, schedule and workspace conflicts.

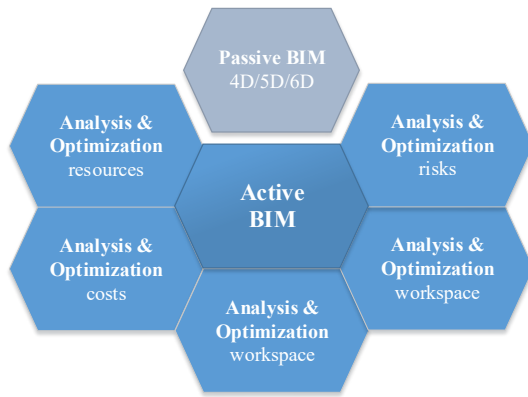


Figure 1. Features of active BIM (Kang *et al.*, 2013)

In this perspective, Figure 2 presents a general transformation of baseline and passive BIM into an active BIM. In case of baseline BIM model, input parameters (i.e. information to BIM) are neither necessarily analyzed nor optimal, and such model results only with feasible solutions of construction. Input parameters (Information to Building Model) are discrete and, in most cases, manually added to the model. Changes of input parameters, which might and more certainly will occur in projects' construction phase, need to be repeatedly/discretely modeled and transferred back to the BIM model. On the other hand, passive BIM approach can involve techniques for parametric analysis and optimization, but not necessarily in a dynamic continuous manner. As a response to drawbacks of previous approaches, active BIM is a dynamic environment of continuous communication and evaluation of input parameters between optimization techniques and nD BIM model. As such, active BIM ensures semi-automated data transfer among models and phases.

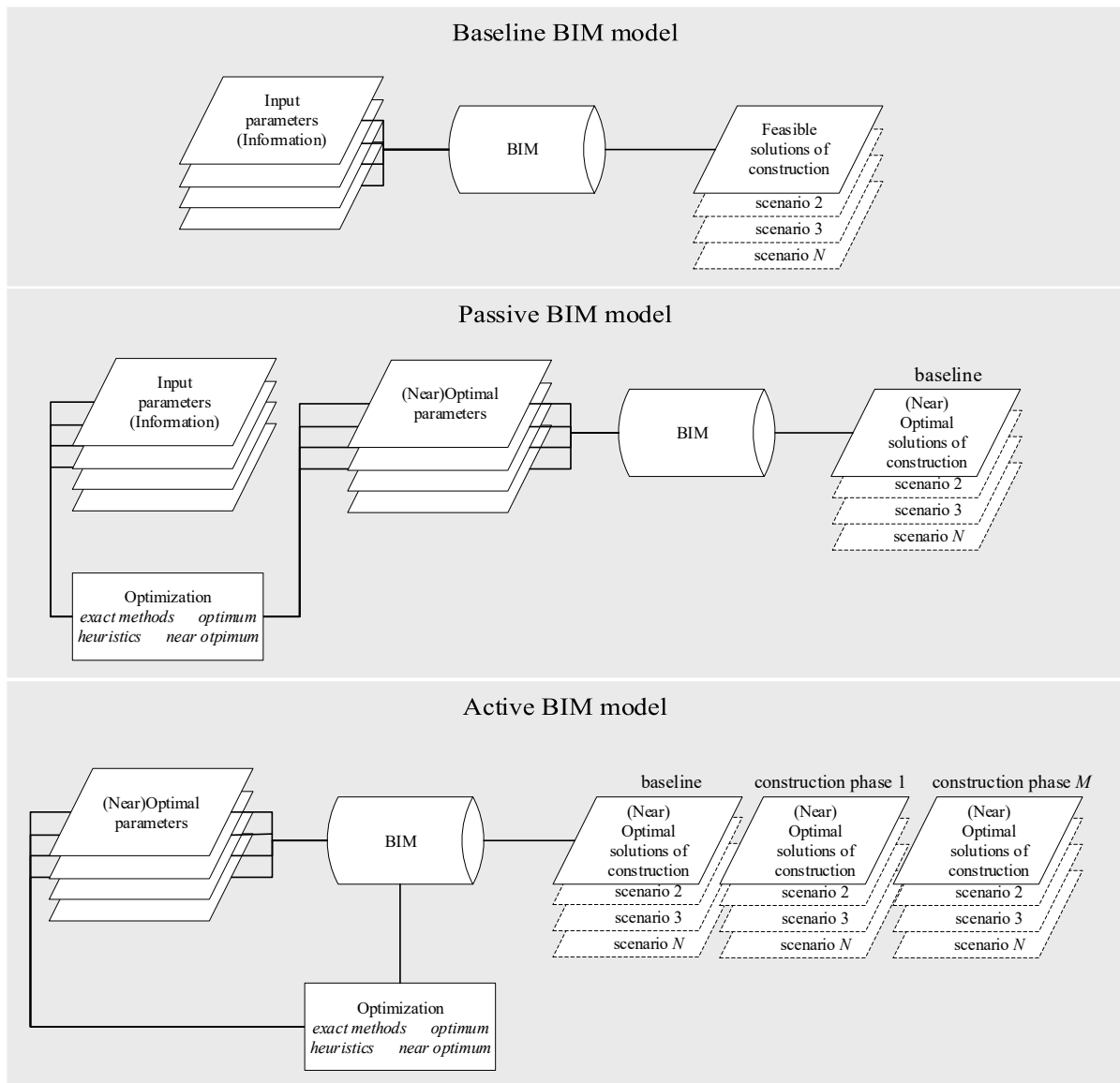


Figure 2. Metamorphosis of BIM into an active BIM

It is important to reckon here that active BIM is dependent on utilized software packages and their compatibility. To achieve active BIM environment with an automated dynamic data exchange, all utilized software have to be compatible, and usually object-oriented.

### 3. Methodology of the review

Authors browsed and analysed 32 published papers containing key words BIM, optimization, active BIM, heuristics, construction projects. From the total number of 32 referenced papers, 25 papers were published in Web of Science Core Collection and Scopus indexed journals (see Table 1), while 7 were published on international symposiums and conferences. Analysed papers were published from 2012-2019. For the sake of papers' clear individual and overall achievements, findings are separated by the presented application of solving primary optimization problems, i.e. resource assignment problems (AP) and construction site layout problems (CSLP); and project scheduling problems (PSP).

Table 1. Alphabetical list of journals that published active BIM related articles analyzed in this study

Name of the journal	Number of articles	Time period of publications
Automation in Construction	10	2014. – 2019.
Buildings	1	2019.
Engineering with Computers	1	2018.
Expert Systems with Applications	1	2014.
International Journal of Simulation: Systems, Science and Technology	1	2015.
Journal of Computing in Civil Engineering	2	2012. – 2013.
Journal of Construction Engineering and Management	4	2013. – 2019.
Journal of information technology in construction (ITcon)	1	2012.
Journal of Management in Engineering	1	2018.
Korean Journal of Construction Engineering and Management	2	2013. – 2015.
Structure and Infrastructure Engineering	1	2016.

The above table shows that even those references that are more than 5-years old were covered here. That at first glance, in state-of-the-art review of IT, may look like outdated citations. However, in spite of rapid development of BIM technology, its active connection with optimization methods has not yet reached high level of maturity and all mentioned references are still actual and relevant.

#### 4. Review of applied active BIM

##### 4.1. Application of active BIM for solving resource assignment problems and construction site layout problems

Numerous papers have been published which present the application, or conditional applications, of the active BIM for solving AP and CSLP. In this chapter, authors present only recent papers which undisputedly and clearly present outcomes of employed optimization techniques with BIM. In this context, one of the earliest papers is the one from (Cheng and Kumar, 2014) where an automated framework to create the dynamic site layout model leveraging the BIM technology was proposed. Authors used Autodesk Revit as the BIM tool and Microsoft Project for making schedules, while genetic algorithm (GA) as an optimization algorithm. The results have shown a reduction of 16.5% over the linear method and confirmed that optimizing the actual travel distance between facilities, generates layouts, which significantly reduce unnecessary site-level transportation. In continuation of their research (Kumar and Cheng, 2015) developed a tool to optimize the dynamic layouts of temporary facilities on a construction site. At this point, the applied optimization method lead to layouts, which reduced the overall travel distance by 13.5% over the conventional methods. For future work, authors are developing a system that incorporates real-time construction schedules for the aim of tracking inventories and managing material logistics.

Akanmu *et al.*, 2016, developed and implemented a component-level system capable of automated generation of construction site layouts. The system involves the integration of BIM,

the GA and the radio frequency identification (RFID) system that has the capability to report object locations in the real-time. The proposed system and results have shown the ability to optimize the site layout planning in terms of costs and space. As well, the proposed system enables project stakeholders to take advantage of available real-time data to react to project issues before delays become noticeable. A similar but more efficient approach was presented in paper by Wang *et al.*, 2014, where authors introduced a system that includes mechanisms for collecting, storing and transferring information among various software packages. The proposed system has demonstrated its effectiveness in enhancing the current 4D applications. As a continuation, Wang *et al.*, 2015, combined BIM and the firefly algorithm (FA) to automatically generate an optimal tower crane layout plan. The findings of this study enable site managers to automatically generate, visualize and simulate tower crane layout schemes. Furthermore, it can significantly help in improving on-site productivity since manual input is quite time-consuming. The proposed approach may also generate savings in total material transport costs and possible collision costs as, due to process visualization, the workers can easily understand and implement the tower crane layout scheme.

An interesting paper by Marzouk and Abubakr, 2016, presented a framework for the selection of tower cranes types and locations at construction sites. The developed model has utilized the analytical hierarchy process (AHP) technique to assist in the optimal selection of tower cranes. Here, the GA optimization was applied to identify: tower cranes layout; type of crane base whether for fixed tower crane or the moving one; shortest rail length that can give higher crane coverage; and lifting assignment plan of lifted modules. The results revealed that the hammerhead tower crane was the most sensitive one since it was associated with the highest sensitivity coefficients.

Paper authored by Hammad *et al.*, 2015, presented a framework for obtaining travel frequencies at different construction project phases by taking advantage of information made available by BIM and project schedules. Using data available from BIM and project schedules, the applicability of proposed methodology was demonstrated in an illustrative case study. The obtained results have indicated the advantageous capability of suggested methodology in automating the travel frequency estimation process.

Authors Moussavi Nadoushani *et al.*, 2016, developed a mixed integer linear programming (MILP) model for crane location optimization that minimizes the total costs. The attained results of tower crane location optimization indicated considerable differences in cases when the capacity of the tower crane was neglected. In the considered case, approximately 30% reduction in total costs has been achieved by applying the proposed MILP model. The results indicated that overlooking the crane capacity requirements in the crane location optimization problem may lead to errors as high as 20% in optimum total costs of lifting operation.

A valuable contribution to the subject is the one from the paper by Amiri *et al.*, 2017, where authors explored the value of using metaheuristic algorithms for reaching an optimized solution. In the said paper, authors presented a review of metaheuristic algorithms (e.g. Firefly algorithm and Genetic algorithm) to support the decision-making process of construction projects with a focus on the BIM-based application of algorithms used during the planning of the layout of a

construction site. They concluded that CSLP is a complex combinatorial optimization problem and needs the use of metaheuristic algorithms to find near-optimal solutions.

Stressing the significance of scaffolding in construction projects, and their impact on overall construction site safety and productivity, authors Kim *et al.*, 2018, introduced a decision-making framework for scaffolding. The proposed framework creates safe scaffolding plans without excessive manual effort and sacrifice of other important construction goals, such as cost and duration. Based on the user's input, various scaffolding plans are automatically created. The framework was implemented in a BIM software tool and validated with a real-world construction project. The results showed that the proposed framework can assist users to efficiently minimize safety risks associated with scaffolding. However, the authors aim to expand and modify their approach in order to incorporate multi-objective optimization.

A study conducted by Cheng and Chang, 2018, resulted with a construction material layout planning optimization model (DCMLPOM). They investigated the optimization of material layout from the perspective of dynamic task scheduling to enhance production efficiency, reduce material transportation costs, resolve the problem of construction site layout, and to facilitate the construction process. The proposed model was applied in the case study. The results revealed that in the fixed material layout plan total distance was 1,659,457 m, and the required total distance for the dynamic material layout plan was 954,736 m. From the aforementioned total distances, it can be easily seen that the dynamic material layout plan saved roughly half of the required distance and the proposed DCMLPOM greatly reduced material transport costs.

Dasović *et al.*, 2019, presented an active BIM approach for optimal positioning of tower cranes and work facilities on construction sites with repetitive operations, utilizing an exact optimization technique. The case study, carried out on the actual construction site of a multi-story residential building, demonstrated that using the active BIM approach can achieve time and cost savings in terms of material transport. Results revealed the total crane operation time savings due to the definition of the crane's optimal position was 34.7 %.

Deng *et al.*, 2019, proposed a 4D BIM-geographical information system (GIS) framework to monitor construction activities and manage construction supply chains. The integrated framework was developed based on four-dimensional (4D) BIM and a GIS for coordination of construction supply chains between the construction project sites and other project related locations, such as supplier sites and material consolidation centers. Based on the results of the study, it was concluded that the selection of suppliers needs to consider both the delivery distance and unit price. Also, the proposed BIM-GIS framework can be modified to consider more real-life conditions.

#### *4.2. Application of active BIM for solving project scheduling problems*

Authors Moon *et al.*, 2012, developed a module that could optimize project management data as schedule conflict and workspace conflict, and also a module that could assess those risks associated with construction works. They suggest configuration methodologies of active BIM functions. As functions for supporting active BIM-operations, this study utilizes fuzzy and GA

approaches. These modules were integrated through a 4D CAD system that was developed in the study. Authors concluded that it is expected that all these advanced functions would be used as basic data for the establishment of active BIM environments.

As an effort of increasing project's constructability, namely minimization of the number of overlapping activities, Kim *et al.*, 2013, suggested a GA methodology to resolve the optimized construction schedule. By using GA, an optimal schedule that minimizes overlapping activities can be created without any change in the initial project duration. Similar approach was developed by Moon *et al.*, 2014, containing an algorithm for establishing a schedule plan with which schedule and workspace interference become simultaneously minimized. To generate schedule alternatives that minimized schedule workspace interference, an improved GA technique based on location constraints was presented in the paper. Based on study results, the value of the schedule-workspace interference impact factor is reduced to 26.4% of the planned value (reduced by 73.6% compared to the plan). Furthermore, Moon *et al.*, 2013, developed a systematic methodology and computer system for an optimal construction schedule simulation that minimize overlapping activities for the enhancement of a project's operational performance. The computer system is divided into subsystems at a schedule overlapping identification stage, a schedule overlap risk analysis stage, and a schedule optimization stage. They applied the GA analysis methodology to find an optimal schedule with the minimum overlapping level.

The research presented by Faghihi *et al.*, 2014, intends to show how the geometric information of a project can be used directly to generate construction sequence. The authors proposed a new usage of GA for developing and generating construction schedules using the geometric information of a project from its BIM. For generating a new schedule, GA and matrix of constructability constraints (MoCC) were used. The experimental results proved that this method can produce 100 % constructible schedules. Same authors (Faghihi *et al.*, 2016) used their previously introduced construction schedule generator algorithm to present graphical relationships between pre-defined objectives of schedule optimizations. The proposed algorithm is able to read through the 3D model input in the form of IFC, detect all structural stability dependencies and relations, and form a MoCC. Then, it uses MoCC as the basis for the GA fitness function to validate the structural stability wellness of the populations and produces project schedules while showing 4D construction animation. This approach has some limitations and one of which is that it takes some time to produce the required number of rounds for GA calculations.

Authors Wang and Song, 2015, proposed a schedule generating automatically scheme based on the integration of IFC rule and adaptive GA. To generate building model, the Revit software was used. Results show that the said algorithm can be effectively applied during construction to automatic generation of construction progress and can generate corresponding constructing progress schedule on BIM model in two complex degrees between simple and complex. Same year the paper was published, Liu *et al.*, 2015, proposed a BIM-based integrated approach for detailed construction scheduling under resource constraints. In order to automatically generate an optimized construction schedule they used: BIM/project model in Revit, WBS information in MS Access, process simulation model in Symphony, and an

evolutionary optimization algorithm. Authors concluded that the system has the following limitations: duration and productivity estimates for work packages are made based on project managers' experience; other factors affecting a construction schedule; weather and work space limitations are not taken into consideration; and part of the simulation network still needs to be established manually.

Xu and Wei, 2015, demonstrated a model that can utilize GA through the establishment of quality, cost and schedule function by which the optimal solution can be obtained. Also, authors concluded that the practical application of the model has to be tested, and the factors affecting the quality of the project construction period are different from the actual characteristics.

The main steps of the methodology, that authors De Soto *et al.*, 2017 presented, include the determination of optimal schedules using Tabu-search algorithm that accounts for single or multiple objectives depending on the project requirements or project management needs, and the integration of project visualization. The presented methodology can be used to determine an optimal construction project schedule, where optimality is defined as the best trade-off between project costs, duration, and fluctuation of resources. Case study resulted in a 13% reduction in the project duration, in 4% cost reduction, and in 49% decrease in resource fluctuation.

Group of authors proposed a facility maintenance management framework based on BIM and facility management systems, which can provide automatic scheduling of maintenance work orders to enhance good decision making. Paper illustrates an integrated approach for collecting and integrating information, algorithms and knowledge for decision making in facility management (Chen *et al.*, 2018).

In the most recently published paper, authors Wang and Rezazadeh Azar, 2019, concluded that automated schedule generation could significantly reduce the time and effort needed to develop a final schedule for construction projects. In order to reduce the time and effort, they developed automated schedule generation system for concrete-framed building projects. The system automatically extracts building objects and their attributes, and then generates list of work-packages, their duration, and sequences. Finally, authors concluded that this approach could be used for initial scheduling of concrete buildings without special architectural and structural complexities.

## **5. Discussion and conclusions**

When efficiency of building alternatives are required to be evaluated during the design- or the construction-phase, the active BIM approach may provide the engaged decision-makers with valuable information. At this point, BIM can dynamically obtain verified (i.e. optimal) information while the optimization results can be simulated along with other information in the project.

The review of recently published papers addressing optimization problems, i.e. CSLP, AP and PSP, reveals evolving nature of active BIM approaches and their promising prospect in near future. This study reveals that BIM has induced heuristic and meta-heuristic approaches of optimization, while exact methods are utilized barely. As regards exact mathematical



programming, currently there were found some attempts to connect BIM with MILP optimization but there still exist many possibilities for further development. The reason for this lies in the scope of semi-continuous information provided by BIM model, e.g. spatial and layout problems do not have to be discretised nor do other functions of resource consumption in relation to construction time have to be. Most authors underline, which is valid for most heuristics, the responsibility of the user in post-optimization analysis and results interpretation. On the bright side, heuristic approaches provide quick and reliable results for complex problems.

Applied active BIM on study cases, presented in this review, resulted with significant betterments of construction time schedules, financial plans, construction layouts, work and resource consumption productivity. The strongholds of active BIM approach are considered its dynamic nature and semi-to-fully automated information flow process. For future endeavours researching this subject, most researchers suggest enhancing active BIM by multi-objective, but dynamic optimization.

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# Diffusion of Awareness and Knowledge of BIM Through the Medium of Podcast

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## Abstract:

This paper discusses the suitability of a podcast (as a medium) on continuing education of AEC professionals. Results are based on the multi-year experience of producing and publishing a technical podcast presenting experiences, background and novelties from the field of Building Information Modelling (BIM). Through a survey, insight was gained about the listeners of the podcast, their usage of podcasts and their perception of the specific podcast. Findings indicate that professionals find the form of podcast interesting, offering them insights into the complex field important for their profession. Suggestions for improvements to current form of podcast are offered and directions for future research are provided. There is still work that has to be done regarding the metrics that would be able to objectively measure the impact and success of the podcast in engineering profession.

*Keywords: engineering education; podcasts; knowledge transfer; technology dissemination*

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## 1. Introduction

Despite the fact that the AEC industry is known to be slow in introducing modern technologies and that it entered the information age relatively late, research shows that its knowledge workers are mostly up to date with the trends and technologies of the modern web. This is also good for the industry itself since small enterprises, typical for most of the construction industries in small countries, are usually too small to be able to continuously invest in technological development. Last but not least, the professional responsibility of any great engineer is the continuous and active learning throughout the professional work in accordance with professional needs and the progress of the profession.

In the last decade the focus of the whole AEC industry has been mostly on the Building Information Modelling (BIM), a different approach to the work and use of a computer in construction at all levels: at the level of individual professional work, level of organization and level of project cooperation (Cerovšek, 2010). Unfortunately, it has been shown once again that the gap between the research and practice is rather profound, despite the fact that it has been known for a long time that innovations can only be introduced into practice when adequate education is provided (Pazlar et al., 2004).

Given the complexity of the process of information modelling of buildings, the necessary comprehensive approach to it, ambiguities and uncertainties around it, the authors of this paper decided to start recording and publishing a niche podcast dealing with this topic. The podcast is aimed at AEC professionals and is on the mission of educating, sharing experiences from the field and starting a discussion on pros and cons of the BIM process.

The main objective of this paper is to present, document and understand the suitability of podcast (as a medium) on continuing education of AEC professionals.

Other objectives of the research are:

1. to identify the strengths, characteristics and purpose of the podcast as the medium for lifelong education;
2. to identify and/or develop metrics for measuring the impact and the success of the podcast in the engineering profession;
3. to identify possible directions for improvement.

## **2. Background**

### *2.1. Podcasting*

The name “podcast” is a mashup of terms iPod (which is a brand of a portable music player from Apple who actually introduced podcasting) and broadcasting. Despite a variety and number of devices from different manufacturers the name stayed and the industry is booming (McGarr, 2009).

Podcasting is described as a method for distributing audio (and video) recordings via the Internet, allowing users to subscribe to a feed of new files (McGarr, 2009; Walton et al., 2005; Lazarri, 2009). On the other hand, we have podcast, which is a term to denote a content of the recording being distributed and that can be consumed anytime, anywhere and anyhow (Jham et al., 2008).

Technically speaking, podcasts are being distributed using RSS feeds containing metadata for the given set of files. Users are then subscribed to the feed and consume the content when it is published since they are notified once there is something new (Fernandez et al., 2008). Fortunately, most of the complexity behind this technology is hidden, therefore users only need to subscribe to the desired podcast using their preferred application on their mobile on any other device.

Despite the perceptible growth of interest, there are only estimations on the number of podcasts that exist since it is impossible to count them due to the decentralized nature of the technology. Morgan (2016) estimated that the number of podcasts is about 200,000 (today this figure is certainly higher), but also pointed out that only 40% of them are active. Many of them are short-lived as they can be done for larger sections of content, the authors achieve their goal after a certain time or simply lose their interest and motivation. As much as 70% of all podcasts are included in the Apple Podcasts (formerly iTunes) directory, which accounts for as much as 80% of the traffic (Willens, 2017).

### *2.2. Podcasting in education*

There has been a lot of research about using podcasts for educational purposes, especially from the perspective of higher education. Most of the researchers concluded that podcasting has potential to enhance learning; nevertheless, it has some limitations.

McGarr (2009) noted that podcasting will most likely not replace traditional lectures due to the shared experience and two-way communication that can emerge in the lecture room but not while listening podcasts. On the other hand, On Tam (Tam, 2012) showed that podcasts helped the students in achieving personalized learning. Researchers presented application of podcast-based education and learning to wide range of domains: music and visual arts (Tam, 2012), palliative care (Nwosu et al., 2017), health professionals (Walton et al., 2005), distance learning (Koppelman, 2013) etc. Although most of them were successful, there are still reports of barriers to using podcasts due to unfamiliarity with technology that resulted in technical problems in accessing and downloading podcasts and that affected learning (Walton et al., 2005; Tam, 2012).

### 2.3. “BIMpogovori” podcast

The authors started the BIMpogovori (which translates to “BIMtalks”) podcast (BIMpogovori, 2019) in April 2016 and publish new content fortnightly. The language of the podcast is Slovenian and is aimed at the professionals in the Slovenian architecture, building and construction (AEC) industry. In 3 years more than 90 new podcasts were produced and published.

Prevailing topic of the podcast is Building Information Modelling (BIM) together with information and communication technologies in construction (ICT). The podcast is usually (but not limited to) delivered in a form of interview between 2 hosts and 1 (or more) guest elaborating on guests’ work in the field of BIM or ICT in AEC.

The podcast was initially available on the webpage as an MP3 file download or in a form of RSS feed. It has also been available from Apple podcasts (formerly iTunes) directory since the beginning. Due to the comments and suggestions that came from the listeners of the podcast it was later also added to YouTube, lowering the barrier for listening even further.

Despite the tendency to measure success of digital projects in numbers, it is really hard to do the same for podcasts. Based on available statistics from the service where RSS feed is hosted (feedburner.google.com) and from YouTube, the number (see Figure 1) of unique subscribers has currently stabilized at approximately 150 (RSS feed, Apple podcasts and YouTube together) while every published show had 90 visits on average.

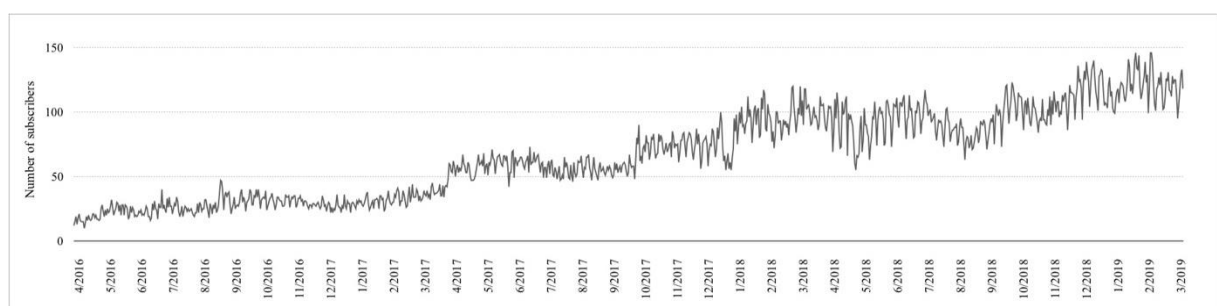


Figure 1: Number of subscribers to the BIMpogovori podcast based on RSS subscribers only (feedburner.google.com).

### 3. Methodological approach

In order to understand if the podcast is a suitable medium for educating AEC professionals and what is their view on the application of podcasting for elaborating on a complex topic such as BIM, a questionnaire was developed. The questionnaire was structured around the themes identified through undertaking the literature review (Walton et al., 2005; sGribbins, 2007; Chan et al., 2006; Chester et al., 2011). The questions measured respondents' familiarity with podcasting, perceived usefulness of podcasting and attitude towards podcasting as well as various technologies they use to access and listen to podcasts. Lastly, two open-ended questions were used to gather additional insight on what they specifically like and dislike about the BIMpogovori podcast.

The survey was divided in three parts: demographic questions, general questions regarding podcasting and BIMpogovori related questions (see Table 1). Questions were structured in a way that navigated respondents through all three parts of the survey based on their answers: if they never listened to a podcast, they skipped parts 2 and 3, and if they never listened to any BIMpogovori podcast, they skipped part 3. This was important due to the fact that invitation to survey was sent to BIMpogovori mailing list and there was no mechanism in place to detect whether all of the subscribers were actually listeners of the podcast.

Table 1. Survey questions.

Part	Question	Type
1	How old are you?	Open
	In which region is your employee?	Choice
	What is the size of your company?	Choice
	What is your current position?	Open
	How is your ICT knowledge?	Choice
	Are you listening to podcasts?	Choice
2	How many podcasts are you subscribed to?	Choice
	How often do you listen to podcasts?	Choice
	How are you listening to podcasts?	Choice
	Are you subscribed to podcasts?	Choice
	Have you ever listened to BIMpogovori podcast?	Choice
3	Where did you learn about BIMpogovori?	Open
	How many BIMpogovori podcasts have you listened to?	Choice
	10 claims regarding BIMpogovori podcasts	5-point Lickert scale
	What do you like the most about BIMpogovori?	Open
	What you don't like about BIMpogovori?	Open
	Do you have something to add?	Open

The survey was implemented using Google Forms and sent to subscribers of the BIMpogovori mailing list. The survey was sent to 76 recipients. The invitation e-mail was opened 37 times (48.7%) and the survey link was clicked 19 times.

The survey link was also advertised on the Facebook page and through the podcast itself. In the end, 33 responses were gathered.

## 4. Findings

### 4.1. Demographic questions

Respondents were from all generations with the youngest respondent being 24 years old and the oldest 64 (see Figure 2). More than half (55%) of the respondents are working in the central part of Slovenia while the others are spread uniformly across the whole country of Slovenia.

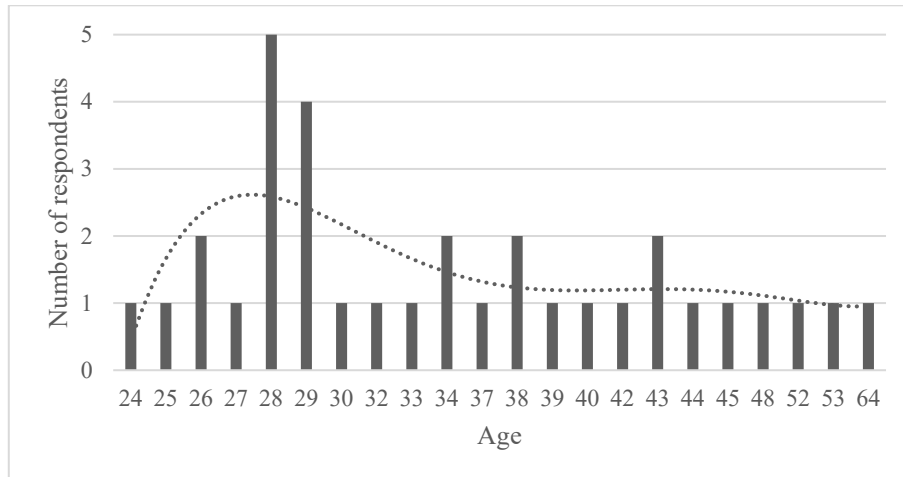


Figure 2. Distribution of age of the respondents (n=33).

45% of the respondents are working in organizations with less than 10 employees (see Figure 3) and they come from all backgrounds of civil engineering, most of them claiming to be structural engineers and BIM coordinators.

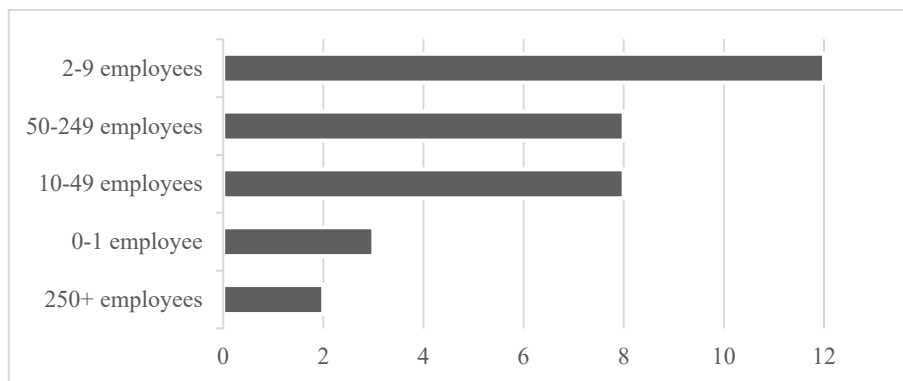


Figure 3. Number of respondents by the size of the company they work in (n=33).

9% of respondents identified themselves as average users of ICT technology, 52% as skilled and 39% as very skilled and technology savvy users. When asked about listening to podcasts in general, 1 respondent answered that he doesn't listen to podcasts and was therefore redirected to the end of the survey and excluded from further analysis.

### 4.2 General questions regarding podcasting



78% of the respondents listen to 5 podcasts or less, which indicates that they are not podcast listeners in general but are intrigued by the content itself (see Figure 4). Only 1 respondent claimed he is listening to more than 15 podcasts.

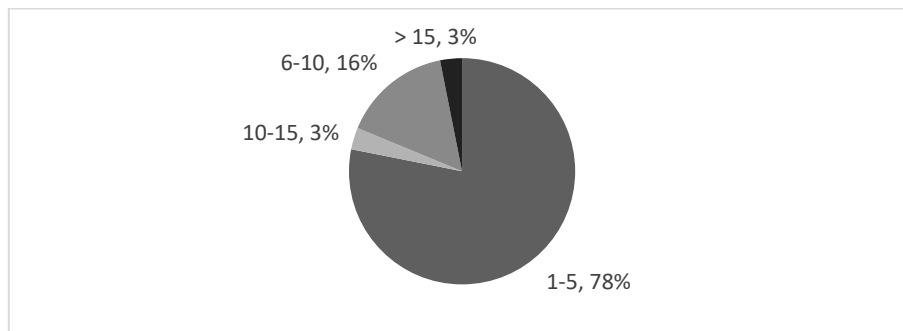


Figure 4. Number of podcasts respondents listen to (n=32).

Most of them (53%) are listening to podcasts using smartphone with dedicated application. A surprising finding is that a quarter of respondents are listening to podcasts on YouTube and 19% of them directly from the webpage.

56% of the respondents are subscribed to the podcast and notified when there is a new show published, while 44% are manually checking for new content. 37% of them are listening to podcasts weekly, 22% monthly, 3% rarely, and 16% daily. 1 respondent added that he listens only to the content he is interested in. Most of them claimed they are listening to the podcasts because of new information, education and to learn experiences from the second hand. All of them have heard at least one BIMpogovori podcast.

#### 4.3 BIMpogovori related questions

Respondents were asked where they have heard about BIMpogovori. They have mostly learned about the podcast either from Facebook or through the membership in the BIM association of Slovenia where the podcast was featured. In addition, some of them have learned about it either from colleagues, from the Internet or from the podcasting app on the smartphone. Most of them have listened to less than half of the published shows while 20% of the respondents listened to all of the shows.

Participants were also asked to rate their agreement with a series of statements (ten subitems) concerning their perception of the BIMpogovori podcast and the learning with podcasts in general. As shown in Table 2, answers were not entirely uniform but nevertheless were inclined to either agree or disagree to specific statements. If we elaborate on the results, we can see that they have no problems accessing the podcast, that they think the content helps them understand BIM and that they have learned new things from it. It is also important to note that the respondents indicated the medium of podcast as a suitable method, appropriate for lifelong learning.

The survey was concluded with three open questions. First two were asking what respondents like and dislike about the podcast. Answers showed that the thing they like the most are the guests, their experiences and easiness of the conversation. The most comments were referring to the length of the podcast and occasional unprofessionalism.

The last question gave respondents a chance to inform authors of the podcast and survey their thoughts on the podcast in a free form. They mostly used this opportunity to express their gratitude for the effort and to write their expectations for the future.

Table 2. Survey questions.

	Five-point Likert scale					Means	
	SD	D	N	A	SA	M	SD
BIMpogovori podcast is not easily accessible.	18	12	2	0	0	1,50	0,38
BIMpogovori podcast helps mi understand BIM.	1	0	3	23	5	3,97	0,53
I have learned a lot of new things while listening to BIMpogovori.	1	0	3	19	9	4,09	0,65
Because of BIMpogovori I am even more interested in ICT in AEC then before.	0	7	10	10	5	3,41	0,99
Medium of podcast suits me well as I can listen and learn whenever I want.	1	0	1	20	10	4,19	0,59
Podcasts are efficient method for lifelong learning.	1	1	4	12	14	4,16	0,94
BIMpogovori podcast is useless.	14	10	6	0	2	1,94	1,18
BIMpogovori single shows are too long.	8	16	4	4	0	2,13	0,86
I have never had any issues regarding access to BIMpogovori podcast.	2	2	1	12	15	4,13	1,30
I think it is important that such podcast exists.	1	0	2	9	20	4,47	0,75

Notes: The number of answers in five-point Likert scale was provided for each item. (n=32)

Legend: SD - strongly disagree, 1; D- disagree, 2; N – neutral, 3; A – agree, 4; SA – strongly agree, 5;

## 5. Discussion

As this research has highlighted, lifelong and professional learning and education can benefit from podcasting. As seen in Table 2, podcast listeners leaned strongly to the positive side and agreed with claims suggesting appropriateness of the approach. This gives our experiment necessary credibility and enthusiasm for the future.

Despite the potential of podcasting to enhance professionals' learning experience, results of the present study suggest that there are things that need to be considered when preparing such content, one of them being the length of the podcast. The answers also indicated that listeners like conversations that are to the point but were also enthusiastic about the casualness and variety of the conversations so results in this regard are inconclusive.

Similar to many other educational technologies in the past, the influence and the uptake of podcasting on the education of professionals will not be determined only by the potential of the technology, but rather by the way in which it is perceived within the professional community. Its use will be strongly influenced by the early adopters which can already be seen from the answers of the survey presented in this paper.

### 5.1. Limitations of the study

When interpreting results of the present study it is important to note the following:

- The number of respondents is relatively low. While this is not entirely true from the perspective and size of the professional AEC community in a small country, it is true from the statistical perspective. The result is that every answer has greater impact on the results that we would like to see and watchful readers probably noticed that one respondent answered completely against all of the others thus impacting the result of the study.
- Most of the respondents characterized itself as highly competent regarding their use of ICT. While this result was expected from the study like this where they were asked about their use and perception of ICT enabled medium, it could point to the problem of technological barrier for less competent professionals that was reported for other ICT technologies many times before.
- One of the significant limitations is also the selection of the statistical sample. While the decision for approaching newsletter subscribers and listeners of the podcast is clear, we are aware that not all of the listeners are subscribed to the newsletter and that the window in which we waited for the responses was probably not long enough.

Overall, we are confident that despite the limitations this research gave an interesting insight into the perception of podcasting as a medium for technology and information transfer among AEC professionals.

### *5.2.Future directions*

A number of suggestions for future research are indicated by the present study. Besides some technical suggestions regarding length of the survey and the frame of the podcast respondents of the survey suggested to focus podcast around highly specialized and specific topics, while others like the direction that was set until now. None of them suggested that they are not benefiting from the podcast so it is safe to say the BIMpogovori podcast will be developed and published further. Nevertheless, the format may be slightly changed in the near future when moving away from the form of interview is anticipated. While the field of BIM is maturing, the questions changed from why and when to how and to answer them, the form will probably have to be changed.

Another direction being explored in the time of writing this paper is the enhancement of the audio with video, resulting in video podcast. While audio has clear advantages while commuting, exercising or performing other work, video podcasts are suitable for tutorials, lessons or merely showing screenshots and are therefore perfect for explaining complex topics, presenting proofs of concepts or specific details in BIM. Advantages or disadvantages of video are yet to be determined.

As for the podcasting in AEC related research is concerned, we will focus on developing the methodology for measuring the impact and success of niche professional podcasts as we are certain that impact cannot be measured by the number of people listening and/or number of downloads.

## 6. Conclusions

The main objective of this paper and study was to present, document and understand the suitability of podcasts on continuing (or lifelong) education of professionals in AEC industry. The results of the survey showed that the medium of podcast is indeed suitable for this purpose since it was well accepted within the community. Despite the publishing period of two years a few rough edges were identified and will be addressed in the future. One of the main strengths of podcasting is the ability to listen to the content in the way listener wants, how he wants and when he wants. This was also indicated through several answers in the survey.

We were not able to adequately identify metrics that would be able to objectively measure the impact and success of the podcast in engineering profession. Besides the statistical problems with small samples the reason lies in the technology itself since views and downloads are spread across variety of access methods and platforms. Part of the reason is also in the AEC industry where information is considered to be competitive advantage and therefore not voluntarily shared. That is why we currently have to rely on the collective feedback from the professional community that cannot be quantitatively measured but can be qualitatively observed. Nevertheless, methodology still has to be developed.

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# Teaching and Lifelong Education on BIM at FCETEA in Maribor, Slovenia

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## Abstract:

The aim of this paper is to introduce the current teaching and lifelong education activities on building information modelling (BIM) carried out at the Faculty of Civil Engineering, Transportation Engineering and Architecture (FCETEA) in Maribor, Slovenia. The article is initially focused on BIM topics covered in teaching subjects associated to construction project management and presents the study process, completed theses and students' participation on international events such as "BIMathlon" and "BIM WORLD Munich". Afterwards, the paper reveals some cases of recently performed lifelong education activities in field of BIM, i.e. at educational event "BIM in Engineering Practice", expert meetings "BIM connects us" and "BIM in Practice" as well as within the framework of operation "Comprehensive Support to Companies for Active Aging of Workforce". The paper is intended to share our BIM experience in teaching and lifelong education including opening these topics to a wider international expert community for discussion and proposals for improvement. Therefore, the article ends with some findings and conclusions.

*Keywords: building information modeling; BIM; teaching; lifelong education*

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## 1. Introduction

Over the last decade, the reception extent of building information modelling (BIM) has considerably enlarged in architecture, engineering and construction (AEC) industry. While companies in AEC sector are faced with an aging workforce and strive to keep up with numerous novelties of ubiquitous digitalization, the accelerated development increases demand for competent BIM professionals. All these circumstances place higher education institutions in a situation where these challenges are to be addressed by updating learning contents and learning methods as well as they encourage them to become even more actively involved in lifelong education of employees in AEC business.

Active learning represents a well-established educational method in civil engineering study programs that covers teaching techniques like student activating and interactive lectures, experiential learning, collaborative learning and project-based learning among others (Lassen et al., 2018). In academia, BIM is recognized as a convenient way for activating and motivating students and there are proposals on how to effectively embed it within taught curriculums (Underwood et al., 2013).

However, the results of recent studies have opened up a space for discussion on issues of integrating different skills into an open BIM approach, especially knowledge areas of coordination, interoperability and clash detection (Kolarić et al., 2017, 2018). Nevertheless, the governments of developed countries are striving to adequately regulate the field of BIM while

simultaneously stimulating its usage in AEC industry (Galić et al., 2017). In this context, the situation of the aging workforce, which often holds a lower level of IT knowledge, makes the necessity for lifelong education on BIM even more emphasized.

This paper is intended to share our BIM experience in teaching and lifelong education. For that purpose, the current education activities on BIM, carried out at the Faculty of Civil Engineering, Transportation Engineering and Architecture (FCETEA) in Maribor, Slovenia, are introduced. The article is initially focused on BIM topics covered in teaching subjects associated to construction project management and presents the study process, completed theses and students' participation on international events such as "BIMathlon" and "BIM WORLD Munich". Afterwards, the paper reveals some cases of recently performed lifelong education activities in field of BIM, i.e. at educational event "BIM in Engineering Practice", expert meetings "BIM connects us" and "BIM in Practice" as well as within the framework of operation "Comprehensive Support to Companies for Active Aging of Workforce". The article ends with some findings and conclusions.

## **2. Teaching on BIM: study process, thesis and internationalization activities**

At FCETEA, education on BIM is carried out during 1<sup>st</sup> and 2<sup>nd</sup> level studies in subjects associated with construction project management like Building Technology, Construction Management, Construction Economics, Project Management in Construction, and Operative Planning. Teaching about creating 4D and 5D BIMs is implemented within the subject Project Management in Construction, which is carried out on two 2<sup>nd</sup> level study programs, i.e. Civil Engineering and Industrial Engineering.

Students in these courses create 4D and 5D BIMs for actual buildings and each year they are engaged in processing different real object from construction practice. Vico Office™ software modules, such as Quantity Takeoff, Task Manager, Cost Planner and 4D Simulation (Vico Office, 2016), and also some other tools, like 4BUILD for cost estimating (HermeS, 2019) and MS Project for scheduling, are used for creating 4D and 5D BIMs.

Work on subject Project Management in Construction is carried out in groups. Each group receives input data in form of a 3D BIM and technical descriptions. Each group is then assigned a set of elements to be analyzed. Thereupon, each group first performs more detailed analysis of elements (dimensions, materials, technology, quantity, etc.). In the following, they obtain data for cost estimation and time planning.

Then first, a 5D BIM is created in Cost Planner module. This is followed by determining activities and their sequence of performance. From this, a 4D BIM is prepared in Task Manager module. Common results of all groups establish for dealt construction a total estimated value and an overall schedule. An animation of construction is also being prepared. Figure 1 shows a scheme of creating BIMs in study process.

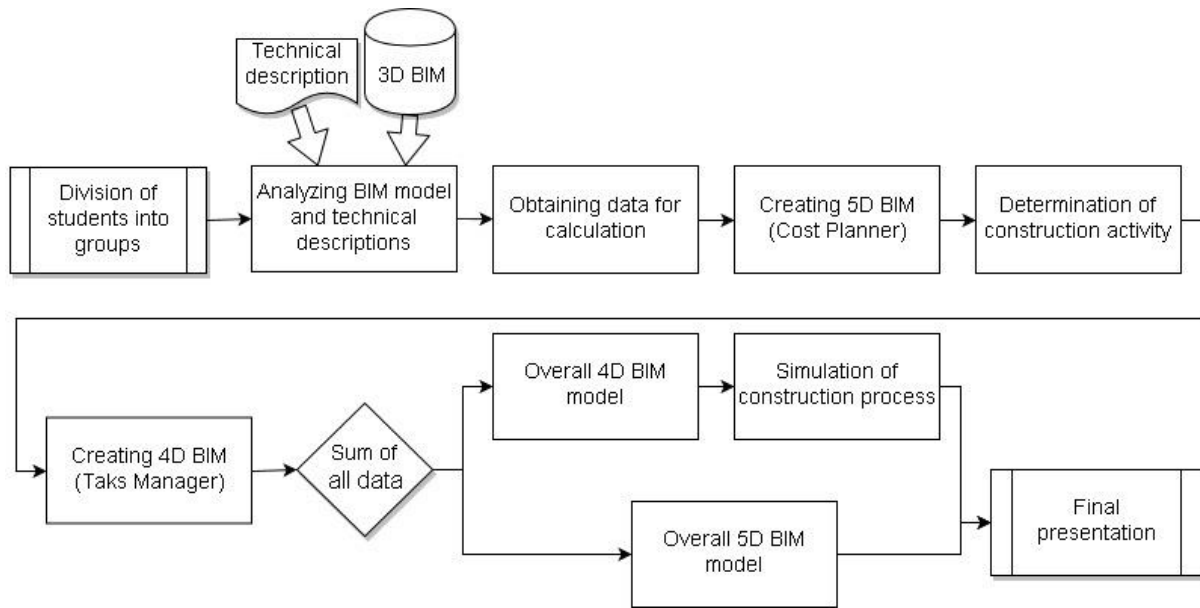


Figure 1: Scheme of creating BIMs in study process

In year 2018/2019, for example, students prepared 4D and 5D BIMs for construction of a business-commercial building LESDOM (Klevže, 2018). In preparation of individual models, students combined all previous knowledge acquired in department's subjects as they were structurally and interdisciplinary oriented towards the comprehensive use of BIM approach in senior years. The presentation of final results was carried out as they were prepared by formed groups in January 2019, see Figure 2. Students were satisfied with final results, i.e. achieved combination of information contributed by all groups in form of a comprehensive BIM model with 4D and 5D features.



Figure 2: Presentation of students' final results in BIM



In recent years, implementation of BIM approach into construction practice has become an ongoing topic for both graduate and master's theses. Last two years, 16 students completed their final theses on various BIM topics. The said theses are available on the web portal Digital library of University of Maribor (source: <https://dk.um.si/info/index.php/eng/>).

Formal education of students on faculty is also supplemented with their participation on events related to BIM. For instance, students recently participated at international events “BIMathlon” and “BIM WORLD Munich”. In November 2016, FCETEA participated with students and teachers in BIMathlon, which represents the international team competition challenge within the siBIM conference (siBIM, 2016). The set challenge was to create the most sophisticated BIM for predetermined object. Further, in November 2018 (in cooperation with the Student Council of FCETEA), FCETEA organized students' attendance at the BIM WORLD Munich Congress, which took place between 26 and 27 November 2018 (Figure 3). More than 150 exhibitors and over 100 speakers demonstrated innovative IT applications around BIM and new technologies for construction, real estate industry and urban planning (source: <https://www.bim-world.de/>).



Figure 3: Students' participation at BIM WORLD Munich (source: <https://www.fgpa.um.si/2018/12/porocilo-strokovna-ekskurzija-v-obersalzberg-in-munchen/>)

#### *Lifelong education at educational events: “BIM in Engineering Practice”*

Learning after formal education needs to be continued in today's world. This was the main motivation for convening the educational event "BIM in Engineering Practice", which was organized by the Slovenian Chamber of Engineers (2017) as part of the project "Implementation of Information-supported Design (BIM) in Engineering Practice". Here, the knowledge transfer on BIM was provided by renowned domestic and foreign experts including those from FCTEA.

On a multi-day event, with a varied set of lectures, participants received information on BIM in order to get employees and general public acquainted with the said approach, which is

becoming more and more a standard in building practice. In particular, the older population of experts, who was not so familiarized with BIM approach, thus received insights into the latest developments and trends in field of BIM including guidelines and requirements for its effective implementation in practice, see Figure 4. In general, it was found that the BIM approach calls for a change in business processes in companies, purchase of appropriate software, and, which is often the most difficult to achieve, greater employee openness for innovation and changes of practice.



Figure 4: Educational event "BIM in Engineering Practice" (Pogačnik, 2018)

*Lifelong education at expert meetings: ‘BIM connects us’ and ‘BIM in Practice’*

FCETEA was also invited to participate at two expert meetings within the 4BUILD Forum (Hermes, 2019). The purpose of mentioned expert meetings was to disseminate knowledge and findings in use of BIM, to establish better connections between companies and academia, as well as to present examples of good practice.

Expert meeting "BIM connects us" (Gradbenik, 2017) was held on November 28, 2017 in Ljubljana with lectures organized in nine content sections, attended by more than 60 participants, see Fig. 5. Participants shared their experience with BIM on actual projects as well as information on new products and software solutions. At this meeting, FCETEA contributed a lecture titled "4D and 5D BIM modelling with examples" with emphasis on modelling and software applications supported by practical cases (Pučko, 2017). The importance of such meetings to enhance cooperation, experience exchange and progress in implementation of BIM technologies was stressed.



Figure 5: Expert meeting "BIM connects us" (Hermes, 2017)

Another professional meeting, entitled "BIM in Practice", took place on 22 January 2019 in Škofja Loka at the Knauf Insulation Experience Center (2019) that was the co-organizer of the event. The meeting was attended by more than 80 participants where 11 lectures as well as a round table were held. Highlights of the meeting were: application of BIM in practical work, state of the art, obstacles in use, solution techniques, and general issues of implementing BIM approach into construction practice. On this occasion, Pučko (2019) conducted a lecture titled "BIM in Education-Practice" which was initially focused on BIM implementation in FCETEA study programs. Afterwards, an example of a research and development project (Šuman and Pučko, 2017) related to BIM-supported construction monitoring, which was carried out by FCETEA in cooperation with partners from industry, was also demonstrated (source: <https://www.youtube.com/watch?v=zj12Cjnc1eQ>).

*Lifelong education within EU co-funded projects: "Comprehensive Support to Companies for Active Aging of Workforce"*

Awareness about potentials of EU funds in supporting lifelong education activities on BIM is present at FCETEA as well as among construction industry. In 2018, FCETEA and the construction company GIC GRADNJE d.o.o. concluded that there is a mutual interest for implementation of development project for the company's staff training in field of advanced project scheduling methods and BIM.

The project was conducted within the public tender of Public Scholarship, Development, Disability and Maintenance Fund of the Republic of Slovenia. The said public tender was co-funded through the "Operational Programme for the Implementation of the EU Cohesion

Policy in the period 2014–2020” under its priority axis “Promoting employment and supporting transnational labour mobility” with the investment priority “Active and healthy ageing” and the specific objective “Prolong and improve labour force participation of the older population participating in measures” (European Structural and Investment Funds, 2014).

Development training for company’s personnel was performed in order to improve the practice of project scheduling which currently runs within the company and to achieve more rational implementation of production processes as well as cost savings. The training was also intended to transfer actual knowledge on BIM from faculty to company and to identify possibilities of its implementation into construction practice. Training participants were acquainted with project scheduling methods and BIM useable in construction industry, both on a theoretical level and in practical terms.

The training was first held in the form of lectures where the participants were presented theoretical backgrounds and the advantages of using the methods discussed. Afterwards, a workshop was carried out where participants in practical training learned how to use the presented methods as a part of their work in the company. The training program covered:

- introductory topics (issues of project scheduling in construction industry; decision-making consequences; possibilities and complexity of project scheduling; qualifications of drafters; extent and effects of project scheduling);
- importance of scheduling (purposes; objectives; benefits; data sources; recommendations for achieving effective outputs);
- types of schedules (classifications according to purpose and subject of scheduling);
- organizational approach to scheduling (team composition; work phases);
- resource lists (materials; labor; mechanization; equipment; hand-held machines and tools);
- time scheduling (determining activities; assumptions and calculations of activity durations; importance of key workers and mechanization; determining activity costs and tradeoffs; compiling work operations or object elements into activities; setting order of activities; generalized precedence relations and their use; creating a network diagram; time analysis; creating a time schedule; critical activities and critical paths; non-critical activities and time slacks; bottlenecks; harmonization of schedules with deadlines; limiting and balancing capacities);
- resource scheduling (tables; Gantt charts; histograms, s-curves);
- theoretical basis of 3D, 4D and 5D BIM; and
- BIM examples of good practices already implemented.

The workshop was focused on practical usage of 3D modelling software, i.e. ArchiCAD (2018) and Revit (2018), scheduling software Microsoft Project (2016), IFC viewer software Solibri Model Viewer (2016) and BIM construction project management software Vico Office (2016), where training participants were educated about software features, system settings, operation principles, data inputs, and result analysis. By the end of the project, providers received valuable feedbacks including information on real-life problems of project scheduling

and BIM in construction practice, which are useful both in improving pedagogical work with students as well as in development of new methods (Klanšek and Pučko, 2018).

### **3. Conclusion**

This paper was dedicated to briefly share our BIM experience in teaching and lifelong education. Therefore, the current education activities on BIM carried out at FCETEA were put in the foreground. The article exposed BIM topics covered in teaching subjects associated to construction project management and presented the study process, completed theses and students' participation on international events. Thereupon, the paper revealed some cases of recently performed lifelong education activities in field of BIM at educational events, expert meetings as well as within the EU co-funded project.

Teaching on BIM during study process at FCETEA takes place through subjects on 1<sup>st</sup> and 2<sup>nd</sup> level studies associated with construction project management, whereby students gradually upgrade their knowledge. At the end of the study, students are qualified to independently handle construction projects with BIM approach. Due to the growing interest and current trends in AEC industry, many students decided to deal with BIM topics in their final theses. Informal education activities, such as students' participation in competitions and international events related to BIM, also contribute to efficient acquisition of competences.

Experience gained in performing lifelong education on BIM at FCETEA showed that effective learning of senior experts in AEC industry is commonly subject to many obstacles connected with lack of time, lower level of IT knowledge, employee overload in business processes and their disinclination to change well-established practice, among others. Although companies in Slovenian AEC sector are already facing changes in business processes on account of accelerated digitalization, it seems that a systematic lifelong education on BIM is still mostly quite overlooked. BIM is not yet regulated by law in Slovenia so it is mostly non-bindingly practiced in those companies that perceived benefits of its usage. Nevertheless, feedbacks received from experts, who have attended the training, indicated that Slovenian companies are mostly aware that BIM will prevail in practice in some near future and there exists a perceived need for practical knowledge from that field.

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# Model and Data Management Issues in Integrated Assessment of Existing Building Stocks

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## Abstract

Building stocks and infrastructures are the largest material stock of industrial economies. These total material stocks on the global scale are about as large as reserves of primary resources in nature. Simultaneously, buildings consume worldwide 35% of energy and produce about 40% of global CO<sub>2</sub> emissions. Due to worldwide rapidly increasing consumption of resources and land, as well as growing generation of waste, increasing of recycling rates and reuse of materials, next to reduction of energy consumption is of highest priority for achievement of sustainability.

This paper presents ongoing research within multidisciplinary research project SCI\_BIM, based on coupling of digital technologies and methods for scanning and modelling (as-built BIM) of buildings. Thereby the laser scanning and photogrammetry is used for the capturing of geometry, and GPR radar technology for assessing of material composition of the occupied existing building as a use case. The algorithms for semi-automatic generation of Scan to BIM process for obtaining information-rich as-built BIM from a Point-Cloud (geometry and material) will be developed and in further steps used for energy modelling and analysis, as well as for the automated compilation of material passports. Finally, using gamification concept through user-participation, the reduction of energy consumption together with automated update of as built-BIM will be tested. The focus of this paper is analysis of the complex interdisciplinary interactions, data and model exchange processes of various disciplines collaborating within SCI\_BIM workflows.

Results show, that the developed methodology, which is accompanied by a cost-benefit analysis, is confronted with many challenges. Nevertheless, it has the potential to serve as basis for the creation of a secondary raw materials cadaster as well as for optimization of energy consumption in existing buildings.

**Keywords:** *discipline models, data exchange, as-built BIM, Material Passports, energy optimization*

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## 1. Problem statement

Currently, buildings are responsible for about 40% of global CO<sub>2</sub> emissions and consume more than 35% of the energy worldwide (Abergel et al., 2017). Additionally, the increasing growth of population and urbanization simultaneously rises the worldwide consumption of material resources as well as the energy demand. The challenge of the future will be to provide sufficient material and natural resources, as well as to minimize the continual amount of waste and energy demand.

The building stock and infrastructure represent the largest material stock of industrial economies, which is, on the global scale, about as large as reserves of primary resources in nature (Brunner and Rechberger, 2017). Therefore, it is of long-term importance to maintain or frequently recycle these urban stocks, and in consequence to minimize the use of primary resources and thus the dependency on imports – a strategy labelled as “Urban Mining”. For enabling successful utilisation of the Urban Mining strategy, detailed knowledge about the existing stock and embedded materials is needed, which is currently lacking. Therefore, in order to build up knowledge of the material composition, assess the performance of the building stock, and enable analysis and prediction, the development of applicable methodologies is urgently needed. Apart from materials information, for prediction and optimization of the energy demand, a BIM-model (Building Information Modeling) is required.

Building Information Modelling (BIM) as emerging digital tool has the potential to support a life-cycle optimization of the built environment (Fellows and Liu, 2012). BIM enables modelling, analysis and optimisation of new constructions as well as of the building stock regarding resources and energy efficiency. Through coupling BIM with scanning methods such as laser scan, photogrammetry and ground penetrating radar a thorough assessment of existing stocks can be conducted; and inventories on detailed material composition of buildings such as Material Passports and simulations regarding energy consumptions, generated. The BIM-based coupling of digital technologies for modelling and analysis has large potentials to support both – reduction of the resource’s consumption as well as the energy demand.

This paper presents the ongoing funded research project SCI\_BIM: *Scanning and data capturing for Integrated Resources and Energy Assessment using Building Information Modelling*, which is conducted at TU Wien. SCI\_BIM is building up on a collaboration of Faculties for Civil Engineering (TU-IBAU, TU-FAR), Architecture (TU-BPI, TU-DAP), and Computer Science (TU-VC) and the central institution for meteorology and geodynamics (ZAMG), as well as industrial partners – two engineering survey companies C1 and C2. The aim of the project is to increase both resources and energy efficiency through coupling of technologies and methods for capturing and modelling (as-built BIM with geometry and material composition) of buildings and assets and finally using gamification concept for the as-built model management by users.

Throughout the research, an integrated data assessment and modelling method is developed and tested on a real case. The capturing of geometry will be conducted via laser scanning, and capturing of material composition via Ground Penetrating Radar (GPR). The suitability of GPR for material capturing and modelling via a semi-automatic scan to BIM process for the generation of an information-rich as-built BIM from a point cloud, will be evaluated in terms of usability as well as costs and benefits. Such as-built BIM models should in a further step enable an efficient generation of Material Passports or BEM - Building Energy Modelling. In addition, the maintenance of BIM models in the life cycle is challenging for facility management. Currently, there is no automated way to transfer changes in the operational stage of a building to as-built BIMs. In SCI\_BIM, a concept which enables the assessment of changes on buildings through the commitment of users based on gamification, is to be developed for the maintenance of BIM models. This innovative gamification concept allows an assessment of



structural changes (users take photos via smartphone, which are uploaded in the photogrammetric as-built BIM within the gamification platform) and of user behavior (such as open windows or lighting) through user participation. Through implementation of user data, the as-built BIM is updated. On the one hand, the structural changes will be captured (static data) and on the other, the user behavior model for operational building automation (dynamic) will be compiled.

As significant innovative contribution of this project is the semi-automated recognition and generation of BIM-Objects from the point cloud, as well as the use of gamification for reducing the energy consumption together with the automated update of the as built-BIM can be identified. The need for research lies in the evaluation of the usefulness of such information rich BIM models for the optimisation of resources efficiency on the one hand and of energy efficiency on the other and will be assessed using cost-benefit analysis.

## **2. Purpose and scope of research**

In this paper, a research gap is addressed – the capturing and modelling of geometry is already well explored, however the methods and tools for capturing and modelling of material composition of buildings are largely lacking. Through this method the automated generation of Material Passports at both throughout and at the end of the lifecycle will be enabled, thus delivering useful information for the material cadaster as well as for the assessment of the material value of a building. As the construction sector is the largest consumer of raw materials, and consumes worldwide 35% of energy and produces about 40% of global CO<sub>2</sub> emissions, it is necessary to analyze and optimize buildings regarding resources and energy efficiency. Therefore, on the one hand it is necessary to have material information about the existing stock, in order to enable recycling of the materials in the stock, on the other hand, it is necessary to optimize the energy consumption of existing buildings. The required focus on the existing stock is strongly intensified through the fact, that new construction rate across Europe is only about 3%, including residential, non-residential and civil engineering sectors (Euroconstruct, 2018).

This particular paper will focus on the analysis of complex interdisciplinary interactions and data exchange process of various disciplines collaborating within the proposed SCI\_BIM platform - planners, surveyors, computer graphics, and software developers, and the handling of their respective discipline specific models and data. Further on, the user-participation issues within this digital eco-system will be addressed as well the employed incentive-mechanisms. Required interactions between the stakeholders, data exchange challenges as well as the workflows will be analysed.

## **3. State of the art**

Due to the expected population growth, up to 9 billion in 2050 (Programme des Nations Unies pour l'environnement, 2011), the demand for natural resources will increasingly rise, accordingly leading to a significant amount of waste. Future challenges will be dealing with the upcoming waste, as well as the supply of sufficient land, material and natural resources. The construction sector is the largest consumer of raw materials, with civil works and building construction being responsible for 60% of the raw materials extracted from the lithosphere

(Bribián et al., 2011) as well as for 40% of energy-related CO<sub>2</sub> emissions (Dean et al., 2016). In order to minimize the consumption of raw materials, the upcoming of waste and environmental impacts, maximizing recycling rates is the main strategy, as proposed by the European Union's (EU) action plan for Circular Economy (CE). CE's aim is to reach a resource efficient and low carbon economy by maintaining the value of materials and resources in the economy as long as possible (European Commission, 2015). The existing building stock thus represents a valuable material stock, and even more - with a rate of new buildings of 2% in the CE area - the achievement of the EU goals 20-20-20 lies in the existing stocks and less in new constructions. At the moment there is a lack of comprehensive knowledge of the exact material composition of the existing building stock, which would allow the prediction of future material flows as well as the increase of recycling rates. Even the assumptions of the energy performance of the existing building stock mostly build up on statistical analyses or energy passes following time categorization.

The application of digital technologies such as Building Information Modeling (BIM) offers extensive advantages in the resource management (Figure 1). BIM allows to apply a life cycle perspective on facilities and construction projects. At the end of the life cycle, at the demolition of an object, stands the waste management, which benefits from a data model with wealth of information. The challenge for using BIM technologies lies especially in digitizing the current building stock and thereby making it accessible to the life cycle orientated management in accordance with the BIM philosophy. However, such methods of capturing are very elaborate and thus the comprehensive data collected by the laser scan and Ground Penetrating Radar (GPR) should be mostly wide used. The BIM models, which are enriched with the exact geometry and material properties, should therefore serve not only as a basis for the material cadastre but also for the life cycle analysis and optimisation.

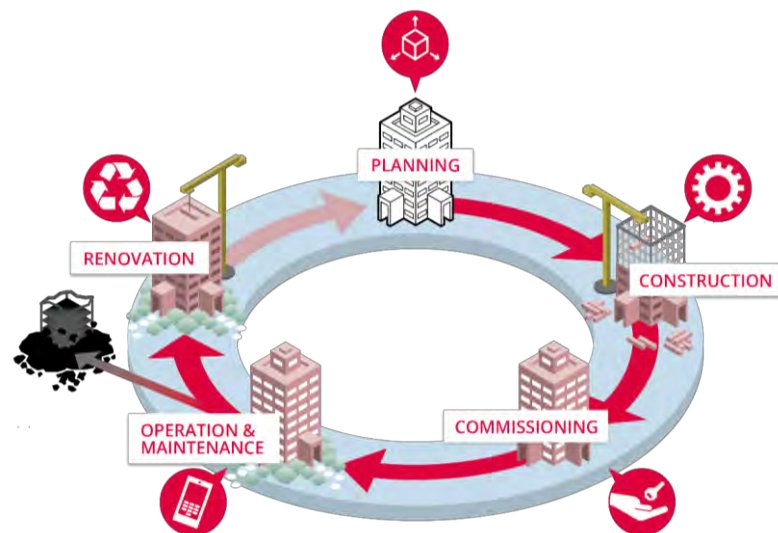


Figure 1: Life cycle of a building (<https://hydronic-flow-control.com/en/page/our-services-building-life-cycle>)

The geometry of existing building stocks is increasingly being assessed by laser scanners, depending on the purpose of the resulting point cloud in colour or monochrome. The major advantage of modern laser scanners is the high resolution in the range of millimetres.

Furthermore, the laser scanner does not rely on an intense light source and can therefore deliver best results regardless of the sometimes-difficult circumstances. With an in the scanner implemented CCD camera, additional images can be captured, which can later be used to provide the point cloud with colour information. Tachymetric surveys are not always required for the positioning, due to the meanwhile very accurately integrated positioning systems, but still helpful in many cases. Due to tachymetrically measured target marks the scans can be precisely georeferenced after the outdoor work and also registered or combined with photogrammetrically recorded images in third-party programs.

The point cloud obtained from the registered scans can either act as the basis for an accurate to the millimetre line evaluation or can be processed into a photorealistic 3D model, so that it is not only available for planners and architects, but also to the populace. The laser scanning technology enables the generation of as-built BIMs, whereby a single scan can generate up to millions of 3D points. For the structure of a model, the examined building has to be scanned from different positions in order to finally merge the generated point cloud into a model, which is currently only possible with a semi-automated process. The generated point cloud can be converted into triangular surfaces, which however cannot be transformed directly into BIM objects. When modelling the BIM the following tasks have to be solved: 1. The geometry of the components must be defined ("Which shape does the wall have?"). 2. Categories and materials have to be assigned to the components ("This is a brick wall.") 3. Relationships and connections between the objects must be established ("Wall 1 is connected to Wall 2 and is located in the second floor").

Thereby, the current state of the art of generation of as-built BIMs from point cloud or voxels is still a mainly manual, time-consuming and error-prone process. Although there are already numerous methods and technologies for capturing data of as-built BIMs, these focus mostly on the gathering of geometry - the gathering of the material composition is currently little explored (Figure 2).

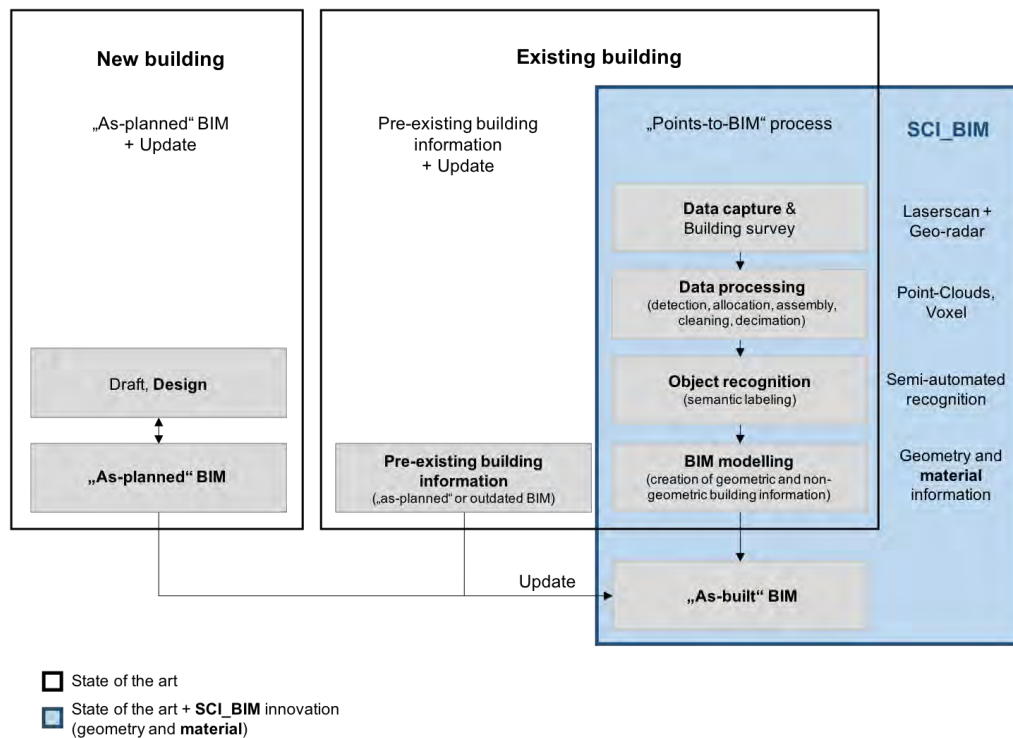


Figure 2: Comparison of the State of the art as-built BIM data processing and SCI\_BIM Integrated Data Assessment and Modelling Method (based on Huber et al., 2011 and Volk et al., 2014)

In this research project, the gamification approach within the BIM environment will be tested through user-participation. The gamification approach, arises from the game industry and is useful for buildings, where it is not possible or too expensive to install sensors. Merschbrock et al. (2014) tested the implementation of a gamification through user-participation in the design stage of a building. Ruppel and Schatz (2011) applied gamification to simulate the user-behaviour during a case of fire. In SCI\_BIM is used to document the “as-is state” of the building as well as to implement the user-behaviour.

In our previous research we developed a BIM-based Material Passport (MP), which documents the material composition of a building. The MP serves as a planning and optimization tool even in early planning phases with regard to the efficient use of materials and subsequent demolition, as documentation for the recycling of buildings and as the basis for an urban material cadastre at the city level. The methodology developed for BIM based MP is very well applicable and serves as basis for "SCI-BIM". The acquired know-how can be further deepened in "SCI-BIM" and extended through integration of energy efficiency aspects as well as user-participation within gamification approach, which is tested on a real use case.

#### 4. Methodology

This research builds up on the interactions of various disciplines, such as planners, surveyors, computer graphics, and software developers, and the handling of their respective discipline specific models and data in order to generate an as-built” model, which serves as material inventory and as energy optimization model. The methodology, as displayed in Figure 3, is tested (or only part of it) on a specific use case, which is a building of an institute of Vienna University of Technology.

The first step in this research was scanning of the use case in order to obtain the geometry and material composition of the building. The geometry was determined through laser scanning (by C1 and C2) and the material composition through GPR-scans (by ZAMG). Thereby C1 was using a very precise point cloud with large data size (high-tech), whereas C2 is using a low-tech variant with lower data-size.

The second step, after creation of the point cloud is the generation of a BIM-model. The generation of a BIM out of point clouds is confronted with many manual steps. In this research, the development of a semi-automated process will be tested. Thereby, the first task, as mentioned in chapter 3, is the automated recognition of surfaces and objects through algorithms. After recognition of surfaces, an automated generation of BIM objects and consequently of the entire BIM-model should be enabled.

After generation of the BIM-model, discipline models are created for further energy assessment on the one hand and for material assessments on the other hand. For further energy assessments, a simplified model is required, whereby for material assessments and follow-up generation of a Material Passport (MP), enrichment of the model through data obtained from ZAMG (GPR scan) is necessary.

In the next steps, two disciplines (energy and material assessments) are working on their specific models in order to generate results for energy demand and resources consumption of the building. Thereby, the aim is to optimize the energy demand as well as to generate a Material Passport of the building, which shows the material composition and the recycling potential of the building materials.

The final step is to gather all data in one model – “as-built” BIM – which is the digital twin of the existing building. Changes in the building, as well as the user behavior are tracked by user participation through applying a gamification concept. Thereby users of the building are connected to the model through a smartphone app, which they fill with required data.

The actual energy demand and material composition will be verified through a comparison of the predicted energy demand with the actual consumption and the material composition through invasive methods. Invasive methods are possible, since the building will be demolished in the near future. The entire process, from scanning to the final “as-built” model, is accompanied by a cost-benefit analysis, in order to evaluate the tested methodology as well as to determine the more feasible variant (high-tech or low-tech) for application on a larger scale (e.g. city level).

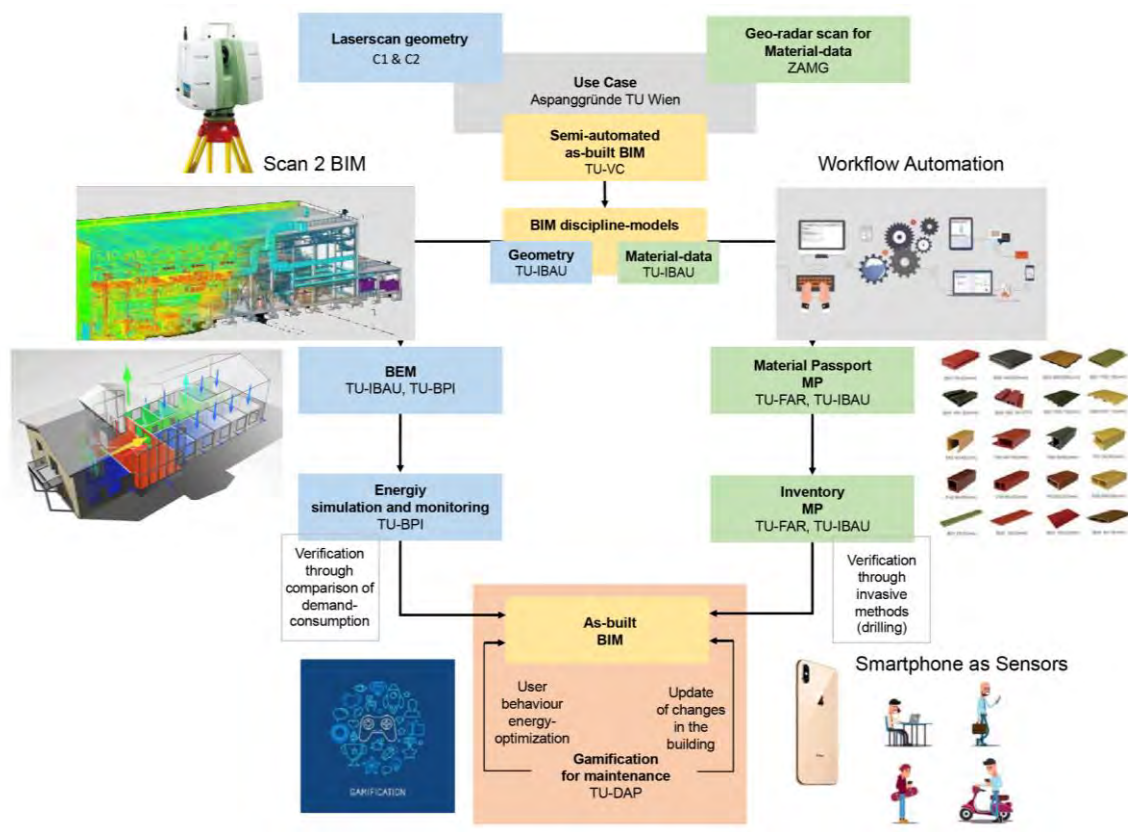


Figure 3: Process-Design

## 5. Findings regarding data management

The aim of the project is to increase the energy and resources efficiency through coupling of technologies and methods for capturing and modelling (as-built BIM with geometry and material composition) existing buildings. Finally, using gamification concept for the as-built model, the building is updated and data is managed. However, the generation of the as-built model and the maintenance of it is a challenging task, since the process requires a step by step data exchange between the various disciplines and a participation of the users. Figure 4 displays the workflow steps: 1) data gathering, 2) pre-processing, 3) model creation, 4) post-processing, 5) data maintenance.

1) **Data is gathered** by the surveyors (C1, C2 and ZAMG), through scanning the use case from different positions inside and outside the building. Thereby the geometry is determined through laser scanning (by C1 and C2) and the material composition through GPR-scans (by ZAMG). C1 is conducting a very detailed data collection of the geometry by using an expensive handheld scanner (device A). C2 tested three different devices for scanning: handheld scanner (device A), low cost scanner which runs on a tablet (device B) and depth camera (device C). Device A is the most expensive one, followed by device B and finally C. Device C was not considered further, as it was not suitable for big rooms and the scanning process takes too much time. Therefore, only devices A and B were used for further scanning. As C1 also uses device A, C2 focused only on device B for the further steps. Both devices generate point clouds, whereby device A creates more detailed point clouds with higher amount of data than device B, which means that C1 tests the high-tech and C2 the low-tech variant.

2) After scanning, **pre-processing** of the point cloud is starting. The created point clouds are joined to one point cloud and reduced in the next step. Point reduction is conducted in PointCab (PointCab, 2019), whereby unnecessary data, such as furniture inside and trees in the surrounding are removed. ZAMG is using a ground penetrating radar (GPR) to scan building components and define their material composition. The identification of the materials takes places through mapping the determined densities (through GPR) with those from a materials list out of a material inventory. The created data format is an Excel-sheet showing the building components and their material composition.

3) The **model creation** is conducted in two ways: manually and semi-automated. For the manual process, the surveyors are responsible. The software used for the manual process is Archicad (Graphisoft, Archicad 2019), whereby the point cloud is imported into Archicad, serving as base for the manual modelling of the building components. The manually created BIM-model by C1 is the reference model, serving as a basis for all other models. C1 and C2 are both generating a BIM-model for the same building, though building up on two different point clouds. C1 is using a very precise point cloud with huge data size, whereby C2 is using the low-tech variant with lower data-size. The investigation of the differences between the created models regarding quality and time-effort, are part of the cost-benefit analysis, as mentioned in chapter 4. The semi-automated generation of the BIM is conducted by TU-VC. Based on Huber et al. (2011) and Volk et al. (2014), as illustrated in figure 2, a semi-automated generation of the BIM-model in Archicad will be tested. However, as the research project is still ongoing, there are no results of this part of the process yet.

4) After the BIM-model has been created, the model is **post-processed** by two different disciplines in order to create on the one hand a BEM (Building Energy Model) (TU-BPI and TU-IBAU) and on the other a BIM for MP (TU-IBAU and TU-FAR). For further energy simulation and prediction a simplification and post-processing (e.g. adding of room stamps) is required in order to prepare the model for the EnergyPlus Software (EnergyPlus, 2019). In order to create a Material Passport for the building, the material information from ZAMG has to be assigned to the components of the BIM-model in Archicad, which is a manual process, conducted by TU-IBAU. A semi-automated creation of the components including geometry and material information will also be tested by TU-VC. For the compilation of the MP, the BuildingOne (OneTools, 2019) database is used, where MP-relevant information is assigned to materials and the final assessment is carried out. As BuildingOne is an Add-On in Archicad, there are no challenges in data management due to the bi-directional interface. The final as-built BIM combines the energy model and material information in one model, which serves as basis for the maintenance of the as-built model.

5) **Data is maintained** through tracking the changes in the building (e.g. removing an inside wall), by which the as-built model is kept updated. Apart from that, the as-built model also serves as basis for energy optimization wherefore user participation is necessary in order to improve the user behavior. Therefore TU-DAP is creating a smartphone app, through which users are connected to the as-built model and supply the app with required information (e.g. window open or closed; wall has been removed etc.). The automated update of the as-built model through user participation through connecting user participation to the BIM-model is one

of the big challenges of this research. Therefore, the required data formats have to be defined and the smartphone app has to be developed.

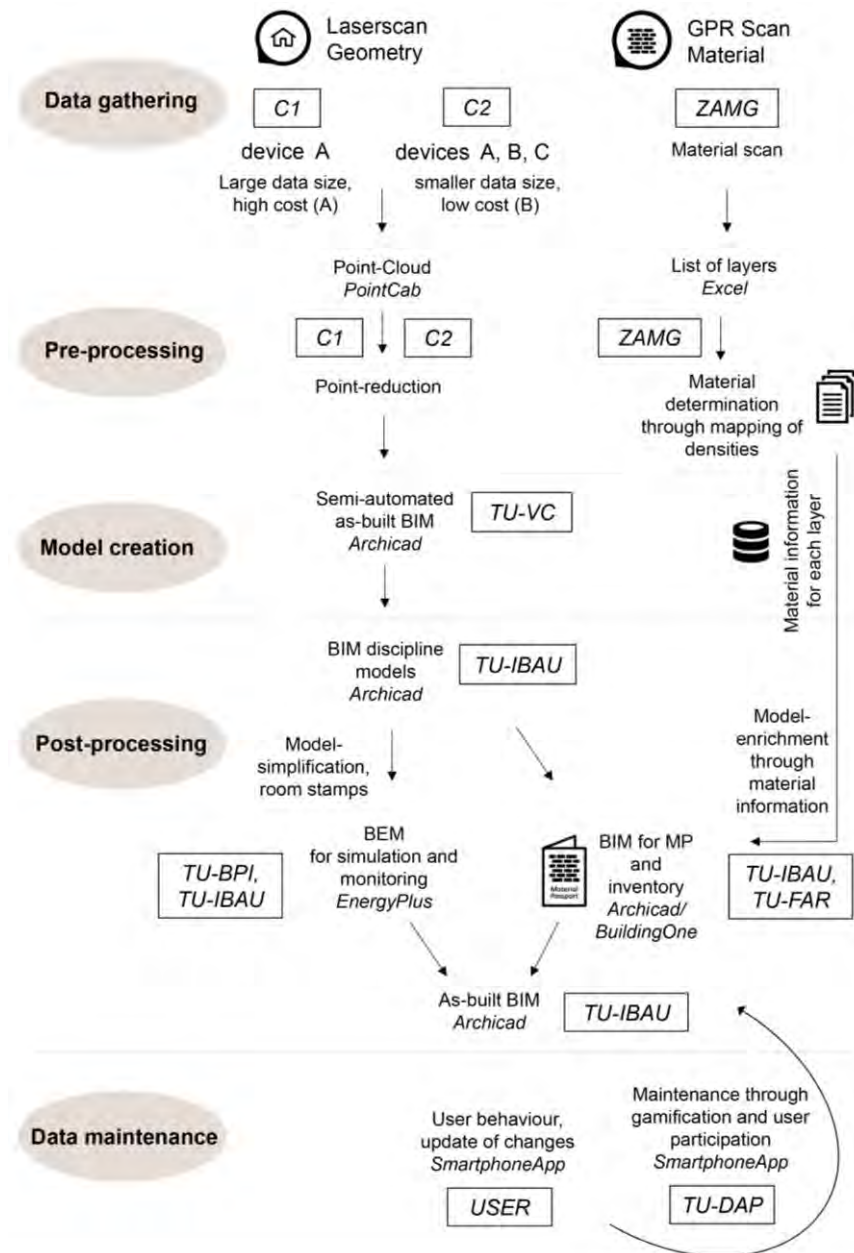


Figure 4: Data and process management framework

### 5.1. Limitations and challenges

One of the main limitations in the data gathering stages is the accessibility of the building. In our research, the building was accessible quite easily from one side, since there is no building closely next to it. From the other side, the building is surrounded by a slope, which made the access to it difficult. Apart from the accessibility, an overload of data occurs (Figure 5), since the building is surrounded by trees and other buildings (far away) outside and is crowded due to existing furniture and users inside, which are also scanned and therefore show up in the point clouds, resulting in an effortful reduction process. Due to the mentioned overload of data, uncertainties occur, since it is difficult to determine e.g. if a scanned object is just furniture or



part of the building in the point cloud. Therefore, it is difficult to verify if the modelled BIM is 100% correct, thus requiring a comparison of the various BIM models (C1 and C2), existing plans and on site observations. As user participation is necessary to keep the BIM-model updated, there exists the risk that the intended workflow does not work, if the users are not motivated to participate. Therefore, the user participation is linked to the gamification app, which should motivate the users to participate in the process through distribution of little prizes for certain achievements (e.g. first person that recognized a change in the building and entered it in the app).

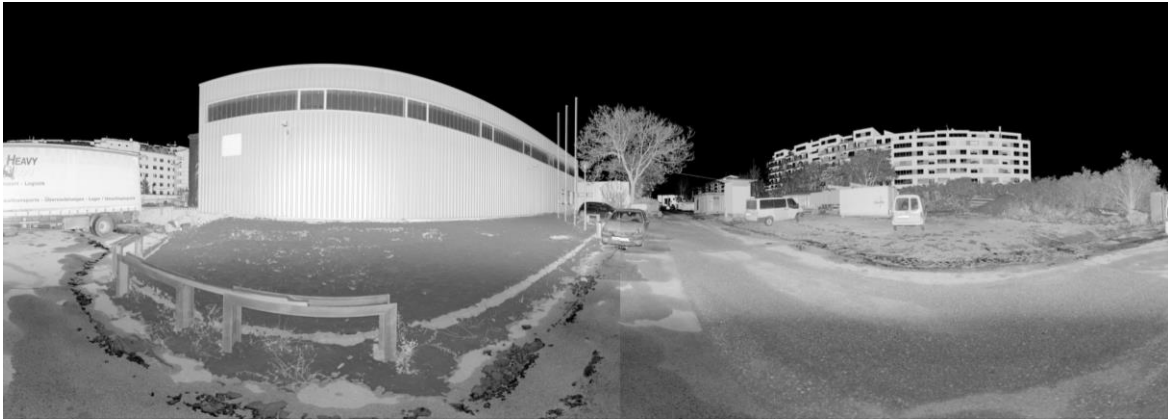


Figure 5: Point cloud of the use case and the surrounding (© C1)



Figure 6: Panorama of the interior of the use case (© C1)

## 6. Practical implications

Throughout this research, a cost-benefit analysis is carried out, in which two variants (high-tech and low-tech) are assessed and compared regarding their applicability on a larger scale. The high-tech variant requires higher costs for the device (A) and produces a high quality point cloud with large data amount, whereas on the contrary, the low-tech variant involves the usage of a less expensive device (B), producing a point cloud with lower data size. The generation of the BIM-model is based on the created point clouds, whereby it will be analysed, if the high-tech or low-tech variant is more efficient for an automated BIM-model generation. The high-tech variant might be more efficient, since a high-data amount might lead to a faster BIM-model generation and accordingly to a more accurate model. There is also the possibility that the high-tech variant leads to an overload of data, requiring a lot of time for pre-processing. The

disadvantage of the low-tech variant might be the inaccuracy of the point cloud and time effort for pre-processing. Advantages of the low-tech variant are the low costs for the device and less data processing, if the obtained data is sufficient. On a large scale, the costs for pre-processing of data is significant, since that costs will accrue each time a building is being scanned and a BIM-model generated, whereby on the contrary, if an expensive device is bought once, it can be used for many buildings and the costs will not add up.

## **7. Conclusion**

In this paper the ongoing research within the research project SCI\_BIM was presented. The project is based on coupling of digital technologies and methods for scanning and modelling (as-built BIM) of buildings in order to optimize the recycling potential and energy consumption of the existing stock. Thereby the laser scanning and photogrammetry was used for capturing of geometry, and GPR-technology for assessing of the material composition of the occupied use case of Vienna University of Technology. The focus of this paper was on the analysis of complex interdisciplinary interactions and data exchange process of various disciplines, such as planners, surveyors, computer graphics, and software developers, collaborated within the research project.

One of the main results is the developed data and process management framework, displaying the core tasks of each discipline as well as the software and data exchange interfaces starting with data gathering and concluding with data maintenance. The main challenge within the workflow was identified as handling of the discipline specific models and data. Other challenges, such as motivation of the users to participate in the gamification process, as well as a data overload through scanning, were faced. In order to enable a smooth data exchange it is crucial to determine the data exchange formats and their interfaces in advance.

The entire process is accompanied by a cost-benefit analysis, which evaluates the developed methodology from scanning to generation and maintenance of the as-built BIM regarding time-effort and costs. Apart from that, the cost-benefit analysis tests the applicability of the developed methodology for generating a secondary raw materials cadastre for a city, which could serve as a basis for many cities and represents a future aim of this research.

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# Key Performance Indicators and 4D Modeling of Metro Rail Projects for Clash Detection Through BIM

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## Abstract:

This research work addresses the identification of Key Performance Indicators (KPI) associated with the design and development of the metro rail station box and optimizing the time duration of the project by utilizing the Building Information Modeling (BIM) and 4D simulation. BIM has been widely used to enhance visualization, clash detection, time management as well by various stakeholders along with the different phases of project life cycle but in the emerging era of complexities the future infrastructure projects needs to be executed more efficiently with minimum time duration. Hence referring to the various available literature, the flaws and limitations can be spotted in the existing extent of research work done on the similar area. Clash detection test helps in reducing the rework by finding the clashes between the various disciplinaries like architecture, structure and Mechanical, Electrical, Plumbing and Fire Safety (MEPF) in the design phase of the complex infrastructure projects. Therefore, by integrating BIM with other dimension i.e. time, an improved and effective timeline simulation can be generated for metro rail station box that will help in building and implementing more complex infrastructure project smoothly within stipulated timeframe in the recent future.

*Keywords: building information modelling, key performance indicators, 4D simulation, clash detection*

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## 1. Introduction

Building Information Modelling (BIM) is a tool for developing and handling all the information on a project along with all the phases of project life cycle. The output of this is the Building Information Model, the digital visual representation of every aspect of the built asset. According to the report of PMI, India has set a huge target of investing USD 1 trillion in infrastructure during the Twelfth Five Year Plan period and also mentioned that cost overruns are fuelled by frequent changes in design and weak planning. It also stated that 79% respondents agree that change in project design results in project schedule overruns in the execution phase. Therefore, the aim of this research is to find the Key Performance Indicators (KPI) with their measurement units to form base for development of the 3D BIM model which can be further used for clash detection in design phase to avoid the design changes and rework in the execution phase. Then after integrating 3D BIM model with the construction activity time schedule, 4D simulation can be done showing the amount of completion of the project with respect to stipulated timeline.

## 2. Literature Review

Manziane et al. (2011) proposed the model for information flow calculation of seven key performance indicators which can be reduce the bottlenecks of project performance due to inappropriate information structure and measurement. Hartmann et al. (2008) conducted the study to analyse the application and issues regarding implementation of 3D/4D in construction projects in USA, Finland, Sweden, Norway, China and South Korea. They have modelled the framework for potential application and potential issues for implementing BIM (3D/4D) in construction industry. Sarkar et al. (2015) took questionnaire survey of 69 respondents for KPI prioritization by factor analysis. Out of 41 KPIs, 15 KPIs have been identified as most crucial KPIs. This have also stated the process flow in logical sequence for effective implementation of BIM in facility management. Since few years, BIM implementation in offsite construction is used rapidly. Due to not usage of common BIM standard has become the hurdle for interoperability of different formats of BIM software outputs. Nawari (2012) developed the “Model View Definition” manual for the information delivery. Becerik-Gerber et al. (2012) stated that conventional construction engineering and management has failed to resolve the issues which have occurred due to improper communication flow between project team members and inefficient management in the AEC industry. They have also incorporated the virtual collaborative approach and construction monitoring from remote location in the project. Mering et al. (2017) derived the framework for integration of risk management and BIM. By this integration, risk can be assessed by stage wise of project. Also, BIM lead the risk management on next floor which can enhance the project performance by project planning as well as project monitoring at micro level. Even, safety risk management plan can be asset if project manager is able integrate safety management with BIM successfully. Sarkar (2016) explained that early clash detection of MEP services is able to gain desired project performance enhancement for Indian urban transportation projects like Mass Rapid Transit Systems (MRTS). This study has also contributed to the AEC industry by developing the outstanding integration framework of BIM and risk management.

## 3. Conceptual Framework

After referring to the various literatures and research papers many Key Performance Indicators (KPI)s where generated and short listed based on the relevancy to the metro rail projects with BIM implementation. The measurement unit were also generated to each KPIs. Below mentioned table specifies the various KPIs and their units with the project life cycle phase bifurcation.

Table 1. Key performance indicators with their measurable units

Key Performance Indicators	
<b>Initiation phase</b>	
	units
Efficiency of BIM tool in infrastructure project	%
Visual impact affecting the success rate	%
Initial cost of BIM adoption	INR or % of total project cost
Extent of land acquisition	Area and time
<b>planning and designing phase</b>	
	units
Accessibility of information by BIM	% of information accessible for BIM
Encouraging use of Renewable energy	% of replacement by renewable sources
Economical benefits after BIM collaboration	INR
Functional and flexible activities arrangement after utilizing BIM	Time saving by scheduling (DAYS)
Effect on overall Life cycle cost of project	% cost saving after BIM implementation
Design flexibility	Time saving after BIM implementation in design (days)
Extent of utility and traffic diversion	% of time reduction inconvenience to public
Number of risk factors detected using BIM	Numbers
<b>execution phase</b>	
	units
Asset utilization in optimized way with collaboration of BIM and IPD	% of cost savings after implementation of BIM
Level Safety management in IPD and BIM	% reduction of injuries and accidents
Waste management after integrating BIM and IPD	% waste saving after implementation of BIM
Ecological footprint after integrating energy simulation	Carbon emission
Efficient change management	Reduction in Nos. of rework
Material consumption	Cost saving by using optimized resources
Number of change orders in project	Numbers
Number of errors and omissions in field	Numbers or %
Number of reworks	Numbers
Percentage of activities completed without schedule delay	%
Rate of passed initial inspections in IPD	%
Total cost conformance by BIM	%
<b>finishing and maintenance phase</b>	
	units
Standardization of process & frequency of updating the BIM & database	%
Access to the database	% of information
Quick / in advance decision making	Time saving
Facilitating access to real-time data	% information
Feature of 'customizable schedule' & 'shared parameters'	% of transparency
Ease of usability / BIM interface	% Rate of usability
Demand / awareness of client to use BIM as FM tool	%
Potentiality of direct & indirect cost savings in using BIM as FM tool	%
Availability of as-built BIM (model) from consultants	% of information
Cost of information gathering	INR
Reliability of collected as-built data	%
Energy consumption in terms of water usage and electricity after BEM	%
Disaster risks (quakes, floods) mitigation by BIM	%
Cost incurred to users (maintenance and use)	INR

## 4. Case Study

An elevated metro rail station box of Ahmedabad metro project was taken as case study to collect all the required design drawing for developing the 3D BIM model of the project under study in Revit. This 3D BIM model acts as base for the further operations like clash detection and 4D simulation and also provides better visualization to the stakeholders associated with the project.

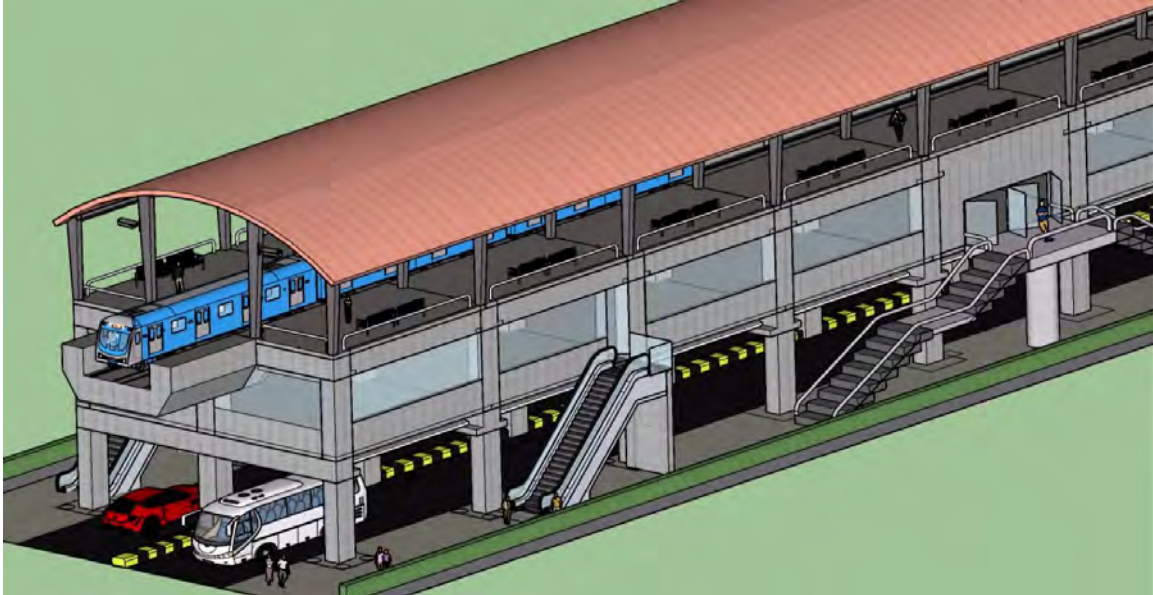


Fig. 1 3D model of elevated metro rail station box

After generating the KPIs and their units with further development of the 3D BIM model, the construction activities with time duration were arranged sequentially in the Microsoft Project Software (MSP) and bar charts were generated with the inter dependencies of the activities required to complete the project.

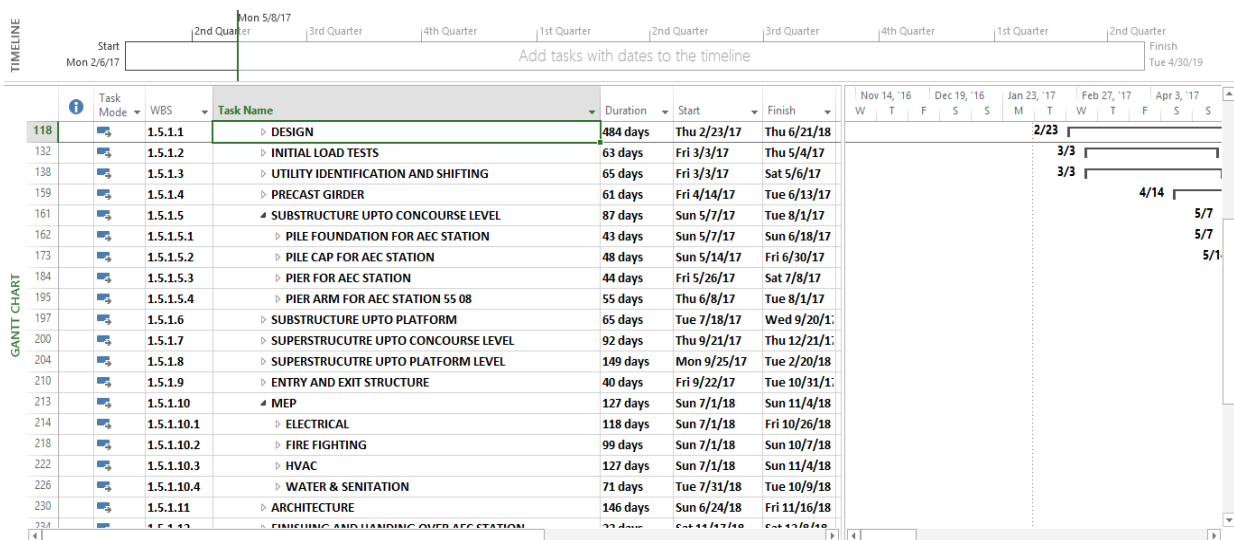


Fig. 2. Construction activities scheduling in Microsoft Project Software (MSP)

## 5. Analysis

After developing the 3D BIM model, it is imported in the Navisworks to run the clash detection test which shows hard and soft clashes between the various disciplines like

architectural components, structural components and MEPF elements. This helps in finding out any potential clash in the design phase only which is likely to happen during the execution phase of the project. Hence then after a clash free model is developed by resolving all the clashes which were shown during the clash detection test.

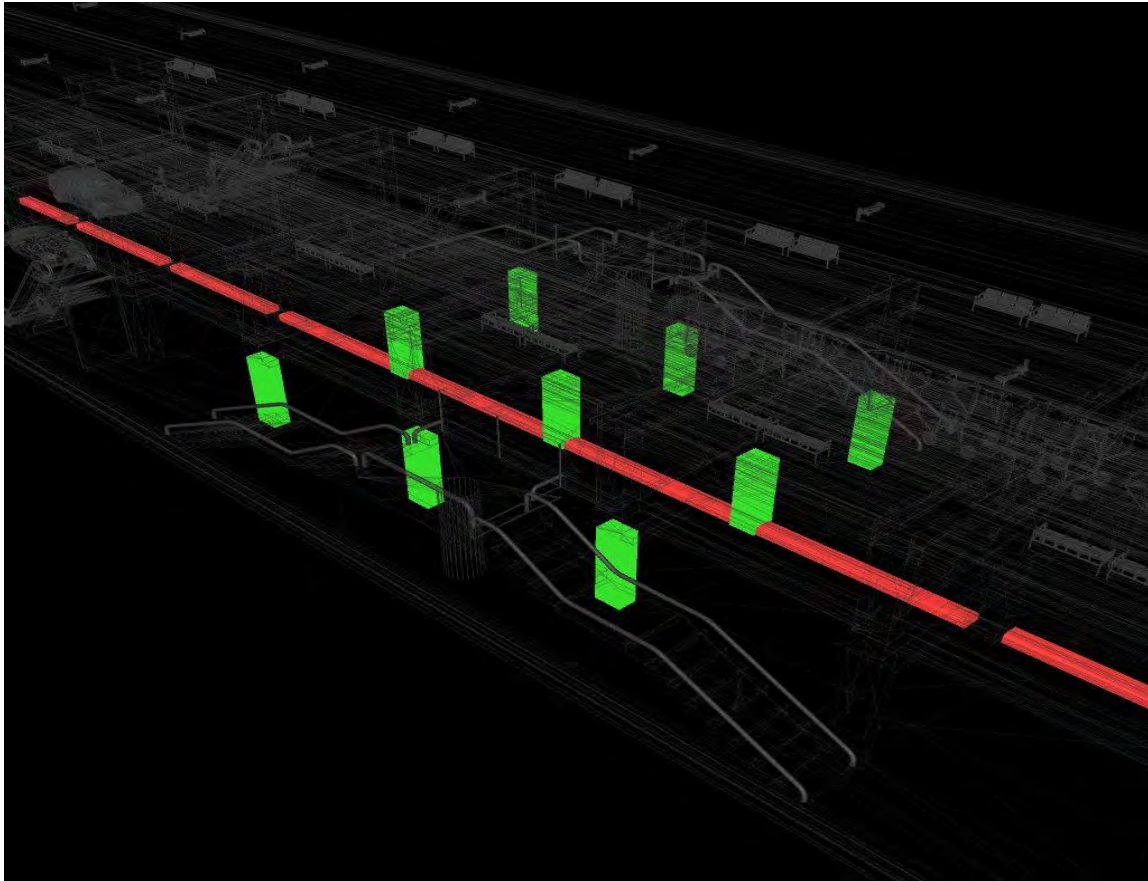


Fig. 3. Example image of clash detection in Navisworks

Further the 3D BIM model is integrated with the MSP file having time schedule of the construction activities. Then all the activities and their time duration are integrated with the respective components of the 3D BIM model to generate the 4D simulation video which will show the timeline displayed with the respective completed 3D model in that stipulated time duration.



Fig. 4. 4D simulation video snapshot showing 3D model with respect to timeline

## 6. Conclusion

After conducting this research work, it can be concluded that there is a vital need for improving the time efficiency of constantly increasing infrastructure with the help of BIM and time simulation. Factors like key performance indicators, clash detection in design phase, scheduling based on time management should be taken into consideration for modifications and improvements to achieve optimized timeline for the project. As time duration involved in the



infrastructure buildings has very significant impact on the total project cost. Hence by minimizing it by using BIM would prove to be an important role towards smooth and successful completion of the complex infrastructure project like metro rail construction.

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# **Construction Design and Technology**

# Blockchain Strategy for Minimizing Information Asymmetry in Construction Projects

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## Abstract:

Good communication between project participants is crucial for success of construction projects. However, there is information asymmetry between project participants even though they work on the same projects and want to achieve the same project goals. Information asymmetry is the situation in which one of the two parties is better informed than the other. One of the best-known applications of information asymmetry in economics is the *principal-agent problem*. Information asymmetry causes communication risk that appears in every phase of the construction projects. Due to complexity of construction projects and the number of participants involved, blockchain technology would help to decrease information asymmetry. This technology ensures that all project participants have access to all the information exchanged between them over the duration of a project. It can thus radically reduce information asymmetries and secure more trustful relationships between project participants. This paper offers a framework for implementation of blockchain technology in construction projects in order to minimise information asymmetry, increase transparency, and enhance trust between project participants.

**Keywords:** *blockchain; information asymmetry; construction projects; trust*

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## 1. Introduction

Poor communication is a common risk that appears in all stages of a construction project. Effective communication between project participants is crucial for project success. According to the Project Management Institute (2013), ineffective communication represents 56% of the total risk in any project. One of the main causes of communication risk is information asymmetry. Information asymmetry is a situation between two parties in which one is better informed than the other, and they do not share the same interests (Jensen, 2000). A survey of project managers (Cerić, 2016) shows that the main strategy for the minimization of communication risk is to build trust between project participants. As temporal organizations, projects deserve special focus regarding the development and maintenance of trust between the parties involved. Furthermore, the project managers surveyed suggested that communication protocols be developed for every construction project. These communication protocols would entail key tools for the project managers to ensure successful completion of construction projects. Blockchain technology can be used in communication protocols to ensure that project participants have access to all the information exchanged between them over the duration of the project.

Construction project management involves issues pertaining to trust in almost every aspect of daily activities. Blockchain makes it easier for two parties to trust each other without a third-

party enforcer (Wang *et al.*, 2017). According to Casey and Vigna (2019), blockchain does not eliminate the need for trust between individuals but serves as its enabler. Blockchain is a peer-to-peer distributed ledger technology, which records transactions, agreements, contracts, and sales” (Christidis and Devetsikiotis, 2016). Therefore, in this paper blockchain is presented as a tool for the minimization of information asymmetry and as an enabler of trust between project participants.

In the following sections, the concepts of information asymmetry and blockchain are first introduced. Next, a framework for the implementation of blockchain technology in construction projects is presented. Special emphasis is placed on communication risk associated with asymmetric information. Thereafter, the conclusions and ideas for future research are presented.

## **2. Minimizing information asymmetry in construction projects using blockchain**

George Akerlof, Michael Spence, and Joseph Stiglitz received a Nobel Prize in economics in 2001 for their work on information asymmetry conducted in the 1970s. Akerlof's “Market for Lemons” (1970) is one of the best-known examples of adverse selection effects, in which used cars of different levels of quality are traded between buyers and sellers (Notheisen *et al.*, 2017; Notheisen *et al.*, 2018). It provides one of the best-known applications of information asymmetry in economics based on the principal–agent theory.

In construction projects the project owner and contractor form the key relationship (Turner and Müller, 2004). The delegation of tasks establishes a principal–agent relationship between the project owner and contractor, wherein the principal (project owner) depends on the agent (contractor) to undertake a task on the principal's behalf (Müller and Turner, 2005). One can act on the assumption that agents try to maximize their own benefit even when if it may involve significant damage to the client (Schieg, 2008). This problem is characterized by three issues of risk concerning the principal–agent relationship: adverse selection, moral hazard, and hold-up. Adverse selection occurs when the principal does not have the exact qualifications of the agent before the contract is signed. In the case of moral hazard, the principal cannot be certain that the agent will fully act on the principal's behalf after the contract is signed. Hold-up occurs when the principal has invested some resources in the belief that the agent will behave appropriately, but the agent acts opportunistically after the contract is signed (Jäger, 2008; Schieg, 2008). The relationship between the project owner and contractor is extended here to include their respective project managers, as illustrated in Figure 1. The project owner is the overall principal and all the others are agents. The contractor is the principal with respect to his project manager. These four participants are crucial in every construction project.

However, it should be noted there is no contract between the project managers themselves; the project owner's project manager monitors the performance of the contractor's project manager, and the latter informs the former. Their conduct is guided by two contracts each, but their direct relationship with each other remains non-contractual. At best, this relationship is based on the guidelines provided by professional organizations concerned with project management and related fields. It should be noted that all the key players in a contract are additionally guided according to principal-agent theory by self-interest. There are 12 relationships in all, six of which are contractual, and six non-contractual. The key non-

contractual relationships are the two between the project managers. As discussed in this paper, these relationships play an increasingly important role as projects grow in size and complexity.

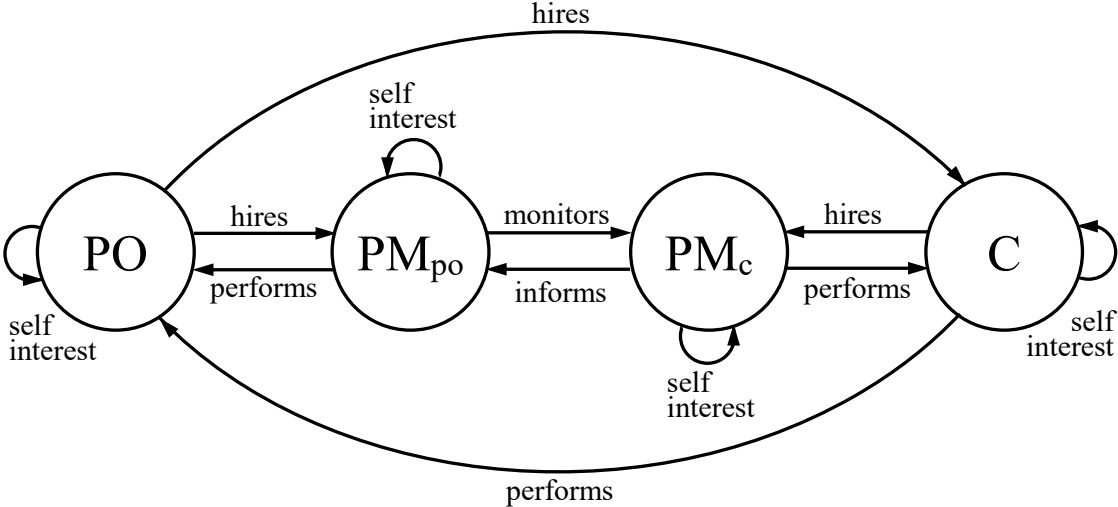


Figure 1. Principal-agent theory framework for construction projects (PO: Project owner, C: Contractor, PM<sub>po</sub>: Project owner's project manager, and PM<sub>c</sub>: Contractor's project manager) (source: Cerić, 2016)

In construction projects, the number of participants grows over time. Figure 2 illustrates the results for up to 10 project parties following the network structure illustrated in Figure 1. Each network is characterized by the project team of project managers surrounded by the principal and all the agents. However, the network structure remains topologically the same throughout.

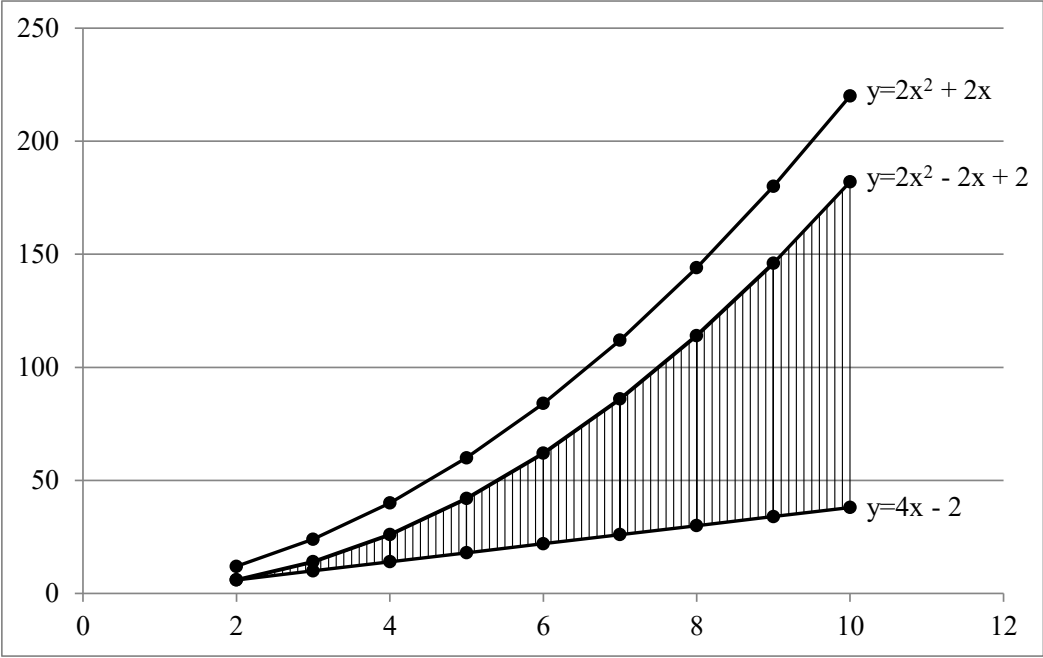


Figure 2. Project parties and relationships for up to 10 parties (Shaded area represents the non-contractual gap) (source: Cerić, 2016)

Figure 3 illustrates the relationships in a project involving three parties. In addition to the contractor, the project owner has hired a designer. The project owner's project manager

monitors the other two project managers, but they are not contractually related to each other. In all, there are 10 contractual relationships regulated by five contracts. However, the designer and contractor are not in a contractual relationship, and neither are the project managers who form the core of the project team. Thus, in the case of three project parties, there are 14 non-contractual relationships among them.

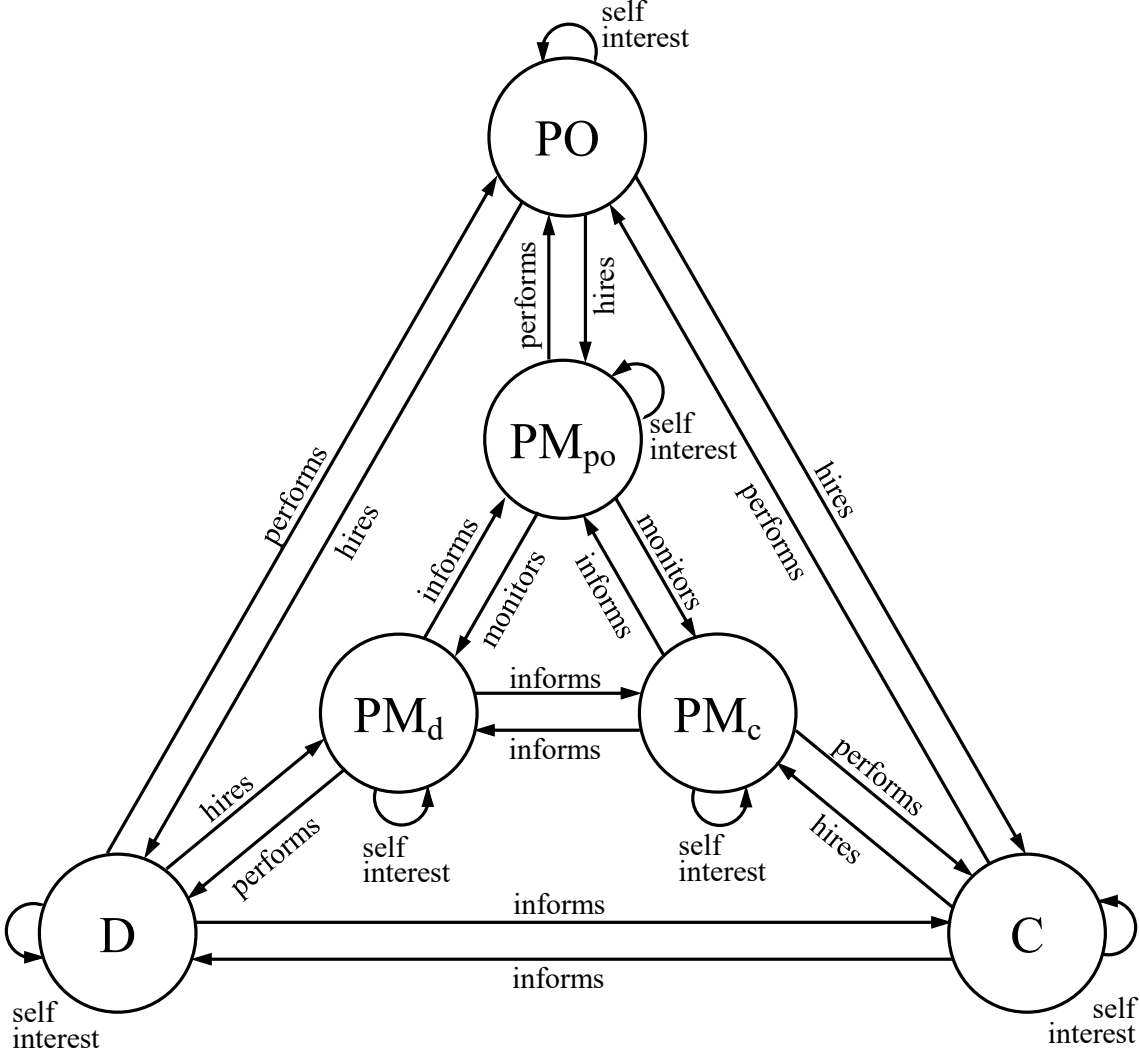


Figure 3. Principal–agent theory framework for construction projects with three parties (PO: Project owner, C: Contractor, D: Designer, PM<sub>po</sub>: Project owner's project manager, PM<sub>d</sub>: Designer's project manager, and PM<sub>c</sub>: Contractor's project manager) (source: Cerić, 2016)

The figures show that non-contractual relationships start to dominate the contractual ones even when there are no more than three project parties. In the case of complex projects that require considerable time for completion, the project team becomes increasingly autonomous from the project owner, as well as the contractor, designer, and consultants as agents.

The first challenge faced by construction corporations is the issue of trust. Blockchain technology can provide a method to avoid information asymmetries and promote more trustful relationships between project participants. In the case of construction projects, blockchain can be used to avoid information asymmetries between key project participants: project owner, contractor, and their respective project managers. Given the complexity of construction projects

and the large number of participants involved, blockchain technology can help decrease information asymmetry. The increasing complexities of buildings and structures alongside that of information flow within supply chains are often diverse and lead to communication gaps and litigation (Heiskanen, 2017). According to Li *et al.* (2019) there is real potential for digital ledger technology to support digitalisation in the construction industry and enable solutions to many of its challenges. From a technical perspective, blockchain is a distributed, transparent, immutable, validated, secure, and pseudo-anonymous database (Bambara and Allen, 2018). It is a distributed file (database) with a specific data structure. There is no central system or server that governs it. Companies or groups of individuals can create blockchain networks using special software and distribute identical copies of the blockchain across hundreds or thousands of computers, which can be viewed as nodes (Gupta, 2017). Blockchain networks can be public, i.e., open to everyone to read and write, or private, i.e., for trusted participants, such as an industry group (Heiskanen, 2017).

There are three categories of blockchain database applications: public, consortium, and private. In the public blockchain database, anyone can read or submit transactions and participate in the consensus process. A consortium blockchain database is controlled by a preselected set of nodes and rules for achieving consensus. The right to read the blockchain can be made open to the public or restricted to a set of known participants. For instance, 10 banks in a consortium agree to the consensus rule that 7 of the 10 banks must sign (approve) a block for it to be considered a valid representation of the truth. A private blockchain database is maintained centralized by a single organization or a part of it (Bambara and Allen, 2018).

However, in markets with asymmetric information, the lack of transparency has implications beyond that of pure technological functionality and can lead to hidden information in the pre-contractual stage and hidden action problems in the post-contractual stage (Akerlof, 1970; Hellmann and Stiglitz, 2000). Minimizing information asymmetry by developing trust between project participants is the key objective in this context. As suggested by well experienced project managers (Cerić, 2016), communication protocols should increase and maintain trust among project parties from the inception to completion of a construction project. Blockchain technology can be used in communication protocols to ensure that project participants have access to all the information exchanged between them over the duration of the project. Hence, in this paper blockchain is presented as a tool for the minimization of information asymmetry and as an enabler of trust between project participants.

### **3. Framework for implementation of blockchain technology in construction projects**

In this section, a framework for the implementation of blockchain technology in construction project management is proposed. The relationships between the key project participants are illustrated in Figure 4. In this case, there are eight project participants during the construction phase of the project: project owner, contractor, construction supervisor, material supplier, designer, structural engineer, and two subcontractors. For the simplicity of graphical representation, the project managers are omitted. Additionally, the arrows depicting self-interest are not shown.

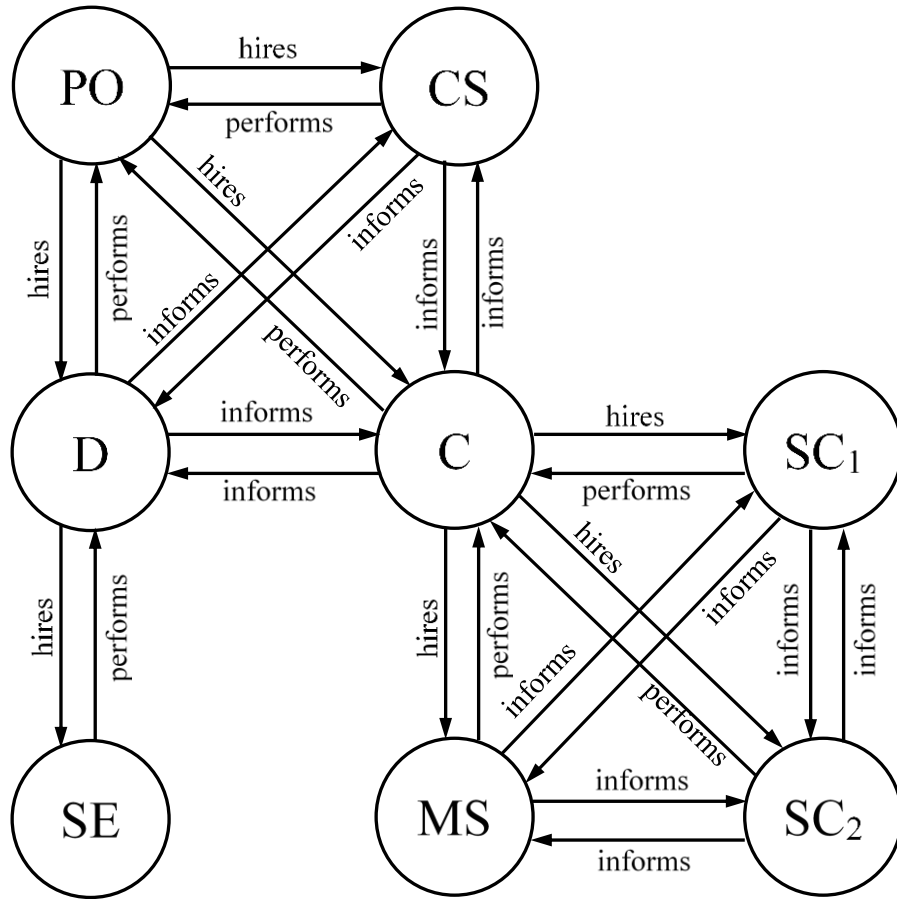


Figure 4. Framework for blockchain implementation: Relationships between key project participants: PO: Project owner, D: Designer, C: Contractor, SE: Structural engineer, CS: Construction supervisor, MS: Material supplier, SC<sub>1</sub>: Subcontractor<sub>1</sub>, and SC<sub>2</sub>: Subcontractor<sub>2</sub>

Table 1 lists the relationships between the project participants, as illustrated in Figure 4. For instance, the project owner hires the contractor and designer, the contractor hires the subcontractors and material suppliers, and the designer informs the site manager and contractor.

Table 1. Relationships between project participants

	PO	CS	D	SE	C	SC <sub>1</sub>	SC <sub>2</sub>	MS
PO	–	H	H		H			
CS	P	–	I		I			
D	P	I	–	H	I			
SE			P	–				
C	P	I	I		–	H	H	H
SC <sub>1</sub>					P	–	I	I
SC <sub>2</sub>					P	I	–	I
MS					P	I	I	–



PO: Project owner, CS: Construction supervisor, D: Designer, SE: Structural engineer, C: Contractor, SC<sub>1</sub>: Subcontractor<sub>1</sub>, SC<sub>2</sub>: Subcontractor<sub>2</sub>, MS: Material supplier, H: Hire, P: Perform, and I: Inform

When one participant *hires*  $x$  participants including the project managers, there are  $2x + 1$  *hire*,  $2x + 1$  *perform*,  $2x^2 - x$  *inform*, and  $x$  *monitor* relationships. The number of contractual relationships is the sum of the number of *hire* relationships and that of *perform* relationships. This number is  $4x + 2$ . The number of non-contractual relationships is the sum of the number of *inform* relationships and that of *monitor* relationships. This number is  $2x^2$ .

In this case, there are eight project participants and eight project managers. The project owner *hires* three participants (contractor, designer, and construction supervisor), the contractor *hires* three participants (material supplier, subcontractor<sub>1</sub>, and subcontractor<sub>2</sub>), and the designer *hires* one participant (structural engineer). There are  $(4 \cdot 3 + 2) + (4 \cdot 3 + 2) + (4 \cdot 1 + 2)$  contractual relationships. Based on previous calculation, it is necessary to exclude four contractual relationships (contractor–contractor's project manager, and designer–designer's project manager) because these are calculated twice. The number of contractual relationships is 30. The number of non-contractual relationships is  $(2 \cdot 3^2) + (2 \cdot 3^2) + (2 \cdot 1^2) = 40$ . Additionally, there are 16 self-interest relationships. In total, there are 30 contractual and 56 non-contractual relationships. As the principal–agent theory shows, even contractual relationships can be guided by opportunistic behavior between project parties.

There are  $(2 \cdot 3 + 1) + (2 \cdot 3 + 1) + (2 \cdot 1 + 1)$  *perform* relationships. Based on previous calculation, it is necessary to exclude two *perform* relationships (contractor–contractor's project manager, and designer–designer's project manager) because these are calculated twice. The final number of *perform* relationships is 15. The number of *inform* relationships is  $(2 \cdot 3^2 - 3) + (2 \cdot 3^2 - 3) + (2 \cdot 1^2 - 1) = 31$ . For 18 project parties, there are  $15 + 31 = 46$  *perform* and *inform* relationships that can deliver asymmetric information. Owing to such high complexity, the main goal of the framework proposed for the implementation of blockchain technology in construction projects is to decrease information asymmetry and provide distributed, transparent, immutable, validated, and secure information.

Blockchain is a distributed database or ledger pertaining to a specific data structure. In the framework proposed, data can be any digital document or file related to construction phase of the project, such as delivery notes, periodic reports, quality control, health and safety issues, resource control, daily logs, tests and inspections, meeting records, work schedules, drawings, technical specifications, daily forecasts, construction diary, photographs, and videos. To share files between project parties, the blockchain is organized as a distributed system without any central point of coordination or control, and hence it does not have a single point of failure alone. A special type of distributed system is the peer-to-peer network. It consists of the individual computers of its users, who are called nodes and communicate through a network. In this case, the project parties (eight participants and eight managers) are the nodes sharing a distributed database. The peer-to-peer system uses the Internet as a network to connect the individual nodes and send files. Each node is identified by a unique address and can disconnect from and reconnect with the system at any time. It also independently maintains a list of all the other nodes it communicates with. Each node has an identical copy of the ledger.

Blockchain works in a way that the distributed ledger is updated whenever one of the project parties wants to inform another about his activities related to the construction phase of the project. For instance, the contractor wants to inform the designer that the underground water level observed during excavation for foundation is higher than that foreseen for the project. The blockchain algorithm on the contractor's computer first converts the message (transaction data) into a 256-bit long string represented by 64 hexadecimal digits comprising digits from “0” to “9” and letters from “a” to “f.” The computer executes this by using the SHA-256 cryptographic hash function that takes an input of any size and produces an output of a fixed size regardless of the size of the input data. Hash is a one-way noninvertible function. It cannot be used to obtain the original data, and hash values do not reveal anything about the content of the input data. Small changes in the input data result in large changes in output. The hash value of the transaction data is called hash reference in blockchain terminology because it refers to the transaction data. Figure 5 illustrates how the hash value dramatically changes when the full stop is replaced with an exclamation mark at the end of the message.

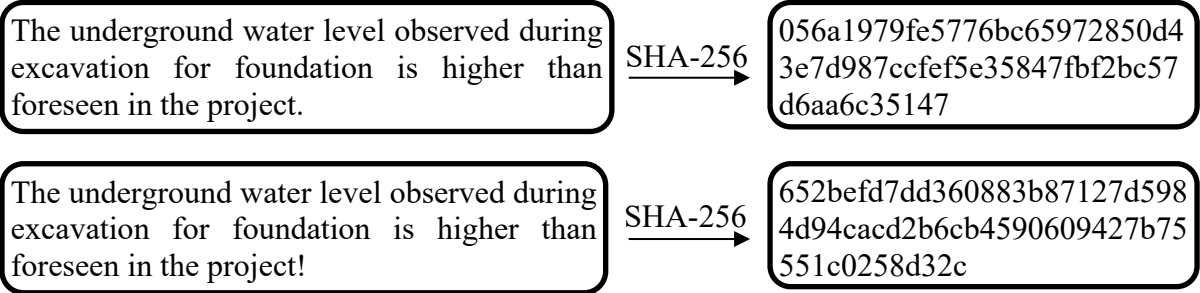


Figure 5. Calculating the hash value of the contractor's slightly different messages

The next step in the blockchain algorithm is to authorize the contractor's transaction by creating a digital signature. The algorithm executes this by using asymmetric cryptography, also called public-private-key cryptography. The goal is to protect the data from being accessed by unauthorized parties. Asymmetric encryption algorithms use two complementary keys to encrypt and decrypt transaction data. One key is the public key, and it is shared with all the nodes in the system. The other is the private key, and it is maintained confidential. If the public key is used for encryption, the private key is used for decryption, and vice versa. The encrypted transaction data is called ciphertext. The contractor's computer creates a digital signature by using its private key to encrypt the hash reference to the transaction data using the Base64 Encoder/Decoder. The digital signature and transaction data are put together and submitted to all the nodes in the system (Figure 6).

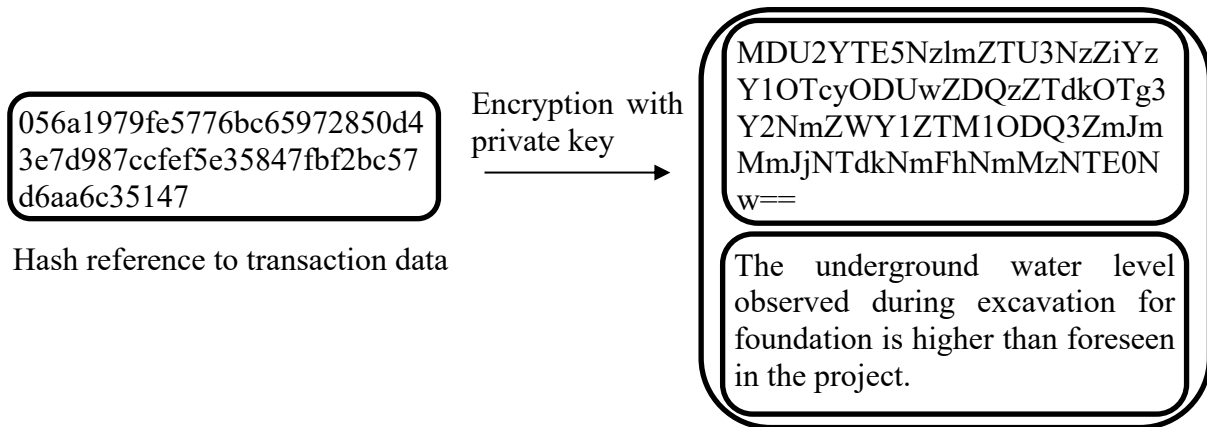


Figure 6. Creation of digital signature of transaction data

When all the nodes receive the transaction data and the digitally signed hash reference to the transaction data, the blockchain algorithm decides which node will create a new block and append it to the chain or distributed ledger. In this blockchain, a proof-of-stake consensus algorithm is applied. The node allowed to append a new block to the blockchain is chosen randomly. This means that the more stake a node owns, the more chance it has to append a new block. The project owner decides the number of blockchain tokens (stakes) each node (project party) receives before the construction phase of the project begins. If there are a total of  $N$  tokens for all the nodes, and node  $X$  has  $M$  tokens, the chance of node  $X$  acquiring the right to create a new block is  $M/N$ . The lucky node is selected every 30 min. The proof-of-stake consensus algorithm requires an attacker to own at least 51% of the total number of stakes in the network to perform an attack, which is very difficult to obtain.

Once a node gets the chance to create a new block, it first identifies the sender, and then verifies the transaction data. Considering the fact that it knows the public keys of all the nodes, it will attempt to use them to decrypt the digital signature. A public key that successfully decrypts the digital signature identifies the sender. The decrypted ciphertext is the hash reference to the transaction data. The verification of transaction data is performed using the digital signature. The selected node first calculates the hash value of the transaction data. It then compares that hash value with the hash reference to the transaction data. If both the hash values are identical, the authorization is confirmed and the transaction is verified (Figure 7). Otherwise, the transaction and data are rejected. Figure 8 illustrates the situation in which a hacker or any node in the system replaces the word “higher” with the word “lower,” and thus completely changes the meaning of the message. Comparing the two hash values reveals that they are not identical, and the transaction is not verified.

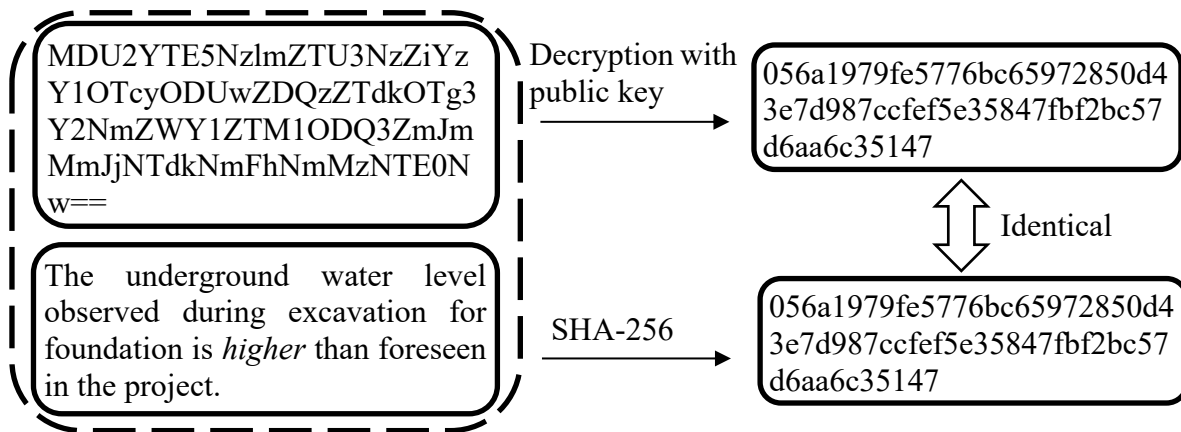


Figure 7. Use of digital signature to verify transaction data

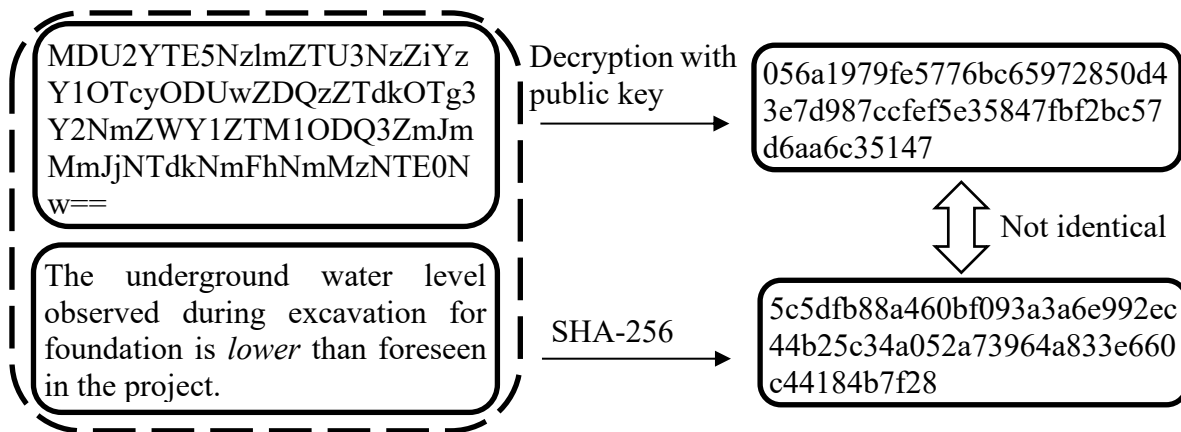


Figure 8. Use of digital signature to reject transaction data

When the sender is identified and the data transaction verified, the selected node creates a new block consisting of the block header and transaction data. The block header comprises the hash reference to the transaction data, current time (timestamp), and hash reference to the previous block. It then calculates the hash value of the block header to obtain the hash reference to the new block (Figure 9). This reference is also called the head of the chain because it refers to the most currently created block in the chain of data. Finally, it digitally signs the hash reference to the new block and submits it together with the new block to all the nodes in the system. Each node then identifies the sender and verifies the entire ledger in the reverse direction from the head of the chain to the transaction data contained in the first block. If the verification is successful, the distributed ledger on each computer in the system is updated and all the copies are identical. If the verification fails, the nodes refuse to update the distributed ledger. When one of the project parties wants to inform another about his new activities related to the construction phase of the project, the entire process starts again.

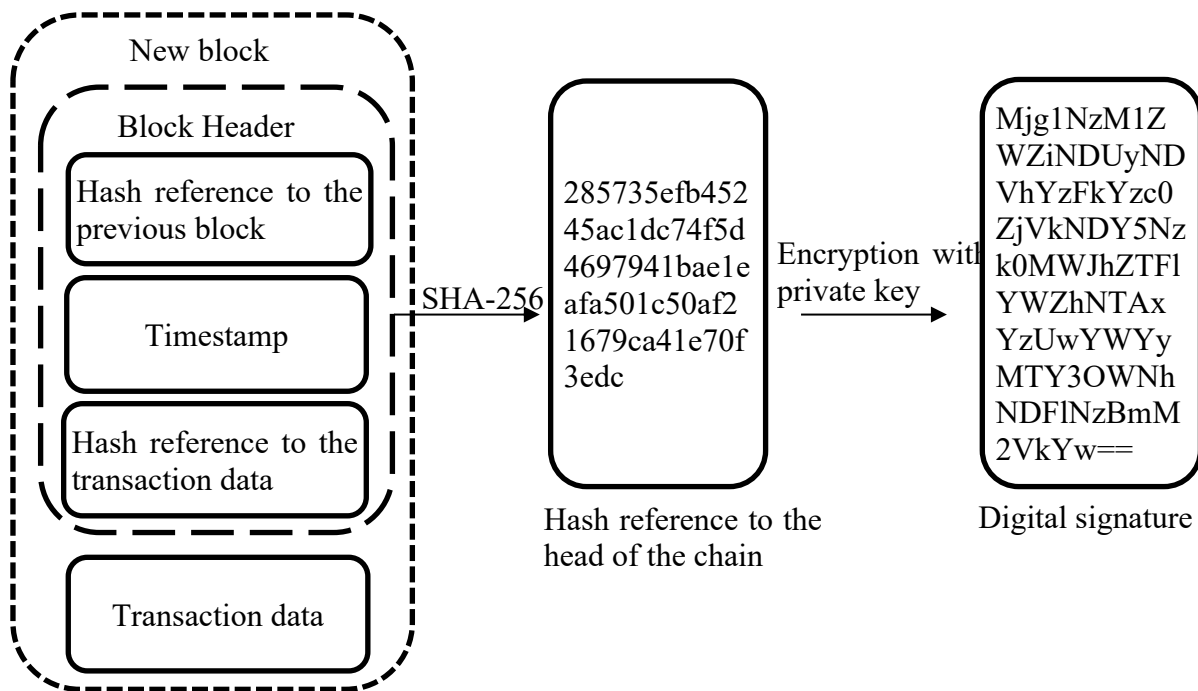


Figure 9. Creation of a new block in blockchain data structure

The framework presented is an example of how the blockchain technology can be implemented in the construction phase of project. It shows how transaction, i.e. information flows between project participants. In construction projects, due to complexity, uniqueness and many changes during construction phase, the whole process of implementation of blockchain technology is more complicated and requires more time than in other types of projects. However, the implementation of blockchain technology in the construction phase is of great importance. It provides transparency and information sharing among all construction project participants. The Blockchain technology can be used in communication protocols to mitigate information asymmetry and enhance trust between them project participants over the duration of the project.

#### 4. Conclusions

Communication risk is one of the most important type of risk that occurs in every construction project, and trust is one of the most effective ways to minimize it. One of the main causes of communication risk is information asymmetry. Information asymmetry is a situation between two parties in which one is better informed than the other, and they do not share the same interests. Owing to the complexity of construction projects and the number of participants involved, the use of blockchain technology can help decrease information asymmetry. In addition, establishing communication protocols using blockchain technology ensures that all project participants have access to all the information exchanged between them during the project. Blockchain helps develop more trustful relationships between project participants.

The main purpose of this paper is to develop a framework for the implementation of decentralized, permissioned, consortium-type blockchain for use in construction projects. The framework proposed offers a distributed, secure, and transparent database that maintains the

entire history of any digital document or file related to the construction phase of the project. It utilizes all the relevant elements of blockchain such as proof-of-stake consensus, asymmetric cryptography for identification, authentication of users, and authorization of transaction data. The main limitation of the framework proposed is that it handles only one digital/file document per transaction. In future work, this can be improved by the implementation of different blockchain data structures capable of managing transactions with any number of files. Furthermore, this new framework would be a useful tool for managing and recording changes to the Building Information Model during all the phases of the construction project.

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# Framework for Automatic Calculation of Life-Cycle Costs of Tunnel Cracks Remediation

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## Abstract:

A paper proposes the framework, which would provide tunnel infrastructure managers with information on life cycle costs for remediation of structural cracks in secondary lining of tunnels. The framework is based on several characteristic phases, where the data between phases is transferred in automatic manner. The continuous, long-term, in-situ monitoring of behavior of tunnel and surrounding rock mass (phase 1) provides input data for the custom-made neural network with back propagation algorithm, which is used to determine constitutive model input parameters necessary for numerical modeling (phase 2). In this way, secondary lining internal forces can be foreseen throughout the tunnel service life, with determination of cracking propagation rate in secondary lining (phase 3). Finally, life-cycle costs are determined using software for cost calculations (phase 4), adapted to the specific purpose, where the sole input of crack width gives a detail insight into life-cycle repair costs including man/hour, equipment/hour, material and other costs. The monitoring data will continuously be used to update and calibrate the crack repair costs, giving the tunnel managers real-time information and opportunity for proactive planning of tunnel maintenance, easing the overall decision-making process.

*Keywords: LCC framework; secondary lining; cracks; maintenance; long-term behavior*

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## 1. Introduction

Tunnels represent an important part of infrastructure networks and their design life is usually over 100 years long, as defined by the Eurocode 1997-1 (CEN, 2004). Within this design code, tunnels are considered as structures of highest structural class, reflecting the importance and usage of structure. The quality of constructed tunnel is conditioned by many factors, ranging from construction technology to selected construction materials, which provide tunnel's long-life performance. However, this performance is highly influenced by the maintenance activities during tunnel's operational phase. The optimization of financial resources allocated for the tunnel maintenance, could lead to further extension of its service life.

Unfortunately, as the result of poor and untimely planning, current tunnel maintenance approach is mostly reactive. Dealing with the problem after its occurrence usually means higher remediation costs in comparison to those if timely measures were adopted. Because of tunnel's ageing deterioration mechanisms and various environmental impacts, reactive maintenance



approach can result in severe consequences, endangering tunnel's performance and safety aspects, which are in focus of many strategic documents, such as EU Directive 2004/54/EC (European Parliament, 2004). Knowing when and where anomalies would develop is important for proactive maintenance. Many authors (Yu et al., 2007; Yao, 2016; Jiang et al., 2019) have analyzed the advantages of using the real-time tunnel monitoring data on tunnel condition, through implementation of the various modern technologies. Lai et al. (2007) state that these technologies would certainly help in understanding tunnel's operational performance and taking appropriate remediation measures in timely manner. Many authors, such as Wang et al. (2016), developed frameworks for tunnel maintenance during its operational phase tunnel management, in order to assist the infrastructure managers in decision-making processes.

A step forward from the state-of-the-art in this field is presented in this paper, which deals with assessment of the tunnel's secondary lining crack development, as the one of the most common structural issues tunnel managers have to deal with. Monitoring data continuously feeds into crack development models, which enable consequent calculation of the life cycle remediation costs. The proposed framework consists of four main phases, Figure 1, which utilizes the advantages of continuous monitoring, neural networks with adapted architecture and advanced numerical models to directly obtain crack remediation costs throughout tunnel's service life.

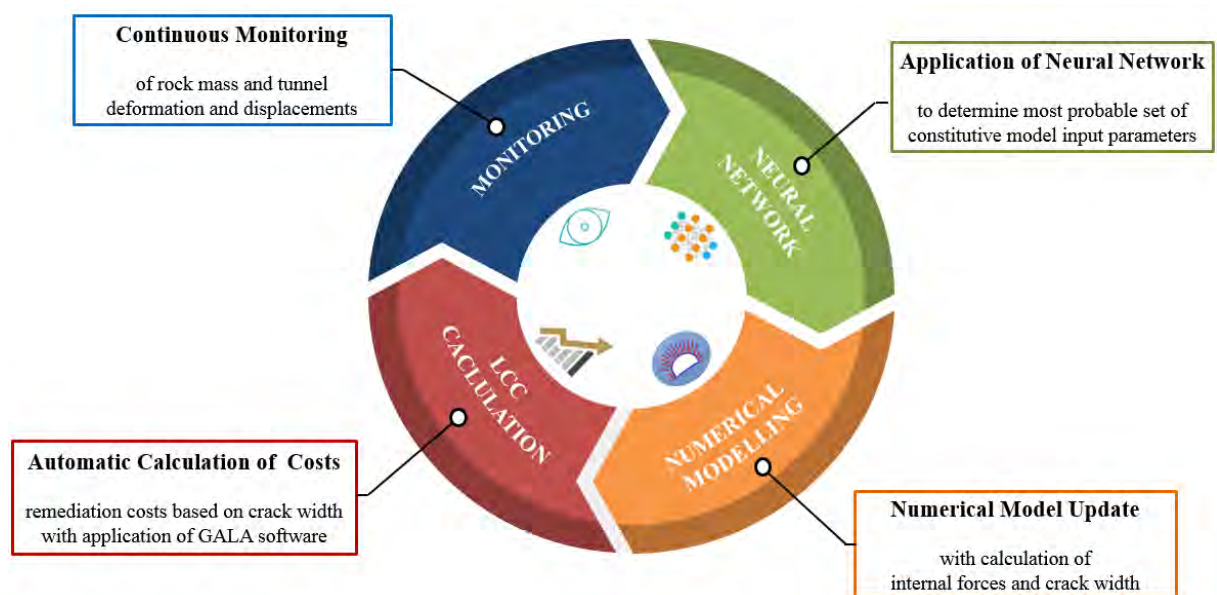


Figure 1. Proposed framework for the automatic calculation of LCC costs of tunnel cracks remediation

The overall framework flow is completely automatic in way that continuous monitoring data is used for continuous calibration of numerical model, and the crack remediation costs are automatically calculated based on the calculated crack width. Therefore, the tunnel managers would largely benefit from the implementation of the procedure, which would facilitate the proactive treatment of cracks in tunnel's secondary lining.

## 2. Secondary lining cracks

### 2.1. Causes of crack occurrence

The majority of rock mass tunnels are constructed using the New Austrian Tunnel Method (NATM) philosophy, which aims to optimize the tunnel support system through the implementation of design as you built approach, supported by the implementation of observational methods. Stabilization of surrounding rock mass is done by implementation of the primary support, which consists of several structural elements (rock bolts, shotcrete, wire mesh and steel ribs). The secondary lining, usually cast-in-place reinforced concrete structure (Figure 2a), should take over only loads of its own weight, tunnel equipment, concrete shrinkage, temperature and aerodynamic pressure of vehicle motion. This, Double Shell Lining system, also includes installation of a waterproofing membrane between the primary support and secondary lining.

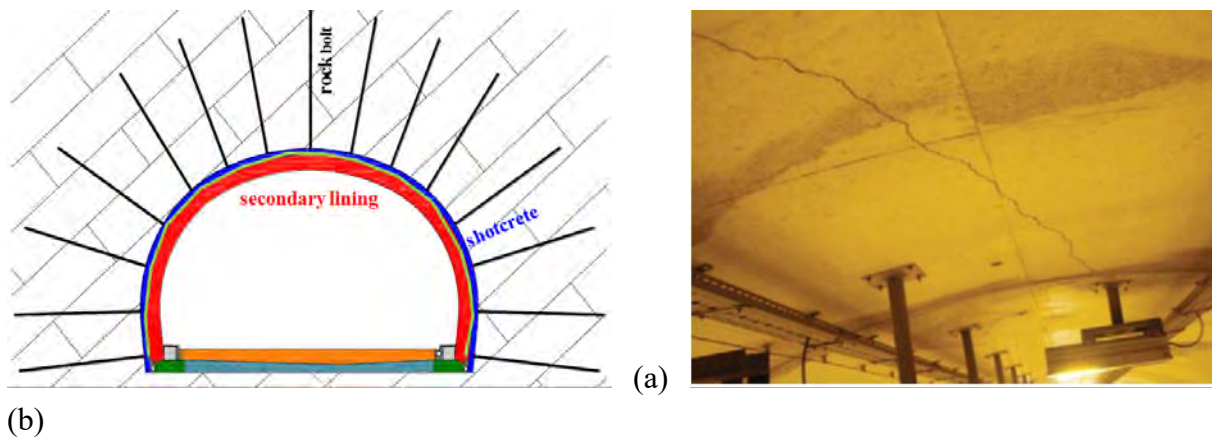


Figure 2. A typical cross section of a tunnel (a), crack on the lining, from Stipanović et al. (2018) (b)

However, the assumption that the primary support will take the rock mass loading during the tunnel service life, leaving no load to be transferred onto the secondary lining, was shown as inaccurate by many researchers (Kovačević et al., 2008.; Sainoki et al., 2017). Extensive measurements of rock mass behavior during the tunnel operational phase has shown significant increase of the rock mass deformations and displacements over time, leading to additional loading of primary support elements, not considered during the design phase. This long-term creep of a rock mass, along with the potential loss of mechanical properties of primary support elements, contributes to the development of long-term loading of the secondary lining. Since the secondary lining has to take over loads resulting from the rock mass creep, for which it was not designed, the cracking of the linings occurs, Figure 2b. As creep is a time-dependent process, larger rock mass deformation lead to further propagation of secondary lining cracks (Xu, 2019). The loss of mechanical properties is usually a result of rock bolt corrosion, as well as shotcrete creep mechanism when loaded over 50% of its strength. However, investigations from ten tunnels constructed over 30 years ago (Galler et al., 2018), show that the rock bolts and shotcrete as part of primary support, showed little or no degradation and loss of mechanical properties, with little or no stress redistribution occurred in the secondary lining.

Secondary lining deterioration is a result of many factors, by some publications (FHWA, 2004) even up to 25 of them. This makes the lining cracking an extremely complex mechanism. The question arises if all cracks have the same impact on the secondary lining condition. Doshi et al. (2018) classify cracks in two categories, structural cracks and non-structural cracks. The structural cracks, which may endanger the structure safety, occur due to incorrect design, faulty construction or over loading, while the non-structural cracks results from the internally induced stresses in structure materials and these generally do not directly result in structural weakness. While the over loading structural cracks are considered in this paper, many researchers, such as Banjad, (2005) analyzed the non-structural crack formation due to concrete composition, which has the highest impact on lining concrete shrinkage and creep. Additionally, the climatic conditions, mostly temperature change, are often stressed out as a cause of non-structural lining cracks (Kovačević, 2004). However, due to complexity of the various influences, and the fact that the concrete shrinkage and creep, as well as temperature change, lead to formation non-structural cracks, these are out of the paper's scope.

## *2.2. Crack remediation procedures*

The remediation of secondary lining cracks is important in order to prevent their further propagation, which could lead to both serviceability and stability issues, such as aggravation of internal reinforced material rust, concrete spalling or ingress of water in tunnel pipe. Ponnuswamy et al. (2016) defined the different classes for crack repair priority, including the critical (requires “immediate” action), priority (when interim or long-term repairs should be undertaken on a priority basis) and routine (for that can be undertaken as part of a scheduled maintenance program). Regardless of the priority, the remediation procedures significantly depend on the crack cause and crack severity, where the cracks width ( $w$ ) is one of the most relevant characteristics, followed by the cracks location and orientation, spatial distribution and depth. The Eurocode 1992 standard (CEN, 2004), recommends the maximal allowable crack width of 0.3 mm and in this situation usually the cracks are not repaired.

When it comes to repairing methods, Monteiro et al. (2017) stress out the significance of European Standard EN 1504 'Products and Systems for the Protection and Repair of Concrete Structures', which includes many aspects related with concrete repair. However, it is up to the designer to choose which repair method is most adequate for certain problem. The FHWA (2004) classifies the crack repair methods to injection/grouting techniques, routing and sealing techniques and packing techniques, but stressing out that it should be known prior remediation of the crack is 'active' or 'passive'. While passive cracks can be repaired, for the active cracks cause of formation should be eliminated and only than cracks should be repaired as passive ones. If the elimination of cause is not possible, a flexible material should be used to repair active cracks. Taking in consideration the necessity for the selection of repair method based on the crack width, which would be implemented into LCC calculation phase, this paper proposes the following methods:

- cracks up to 0.3 mm width – no repair is necessary
- cracks 0.3 - 2 mm width - repair by the low pressure injection of low viscosity epoxy resin

- cracks larger than 2 mm width – repair with filling material, with cutting of U or V shaped groove, and then filled with modified epoxy resin or elastic caulking material.

Some other secondary lining repair and strengthening methods can be also found in literature, for example implementation of fiber reinforced polymer (FRP) as given by Jiang (2017).

### 3. Long-term monitoring of rock mass tunnels

The importance of observational methods for long-term monitoring of tunnel behavior is emphasized in key design code Eurocode 1997-1 (CEN, 2004) which states that '*...for structures that may impact unfavorably on appreciable parts of the surrounding physical environment, or for which failure may involve abnormal risks to property or life, monitoring should be required for more than ten years after construction is complete, or throughout the life of the structure*'. The monitoring parameters usually considered for the long-term stability of tunnels include both horizontal and vertical strains and displacements of rock mass, as well as strains within the primary support and secondary lining. The monitoring system consists of a range of different equipment such as survey points, inclinometers, deformeters, extensometers, measuring anchors, strain gauges, etc., all which are used to determine the rate of the rock mass and secondary lining deformations and displacements over time. This is of significance, since worldwide measurements of long-term behavior of rock mass surrounding tunnels have shown increased trends of measured values.

One typical example of continuous increase of measured values over time is given here for tunnel Pećine, located on D404 road in Croatia. The construction of the tunnel started in 2005, while the last part of secondary lining was finished in 2008. An intensive monitoring program was implemented and continuous measurements are conducted from the start of construction until today. The program includes measurement of deformations and displacements using standard survey points as well as geotechnical measurements of inclinometers and deformeters installed from terrain surface to tunnel depth (Figure 3a). Measurements are carried out on a number of monitoring profiles, with the aim of providing insight into rock mass behavior during construction and in operational phase. The measurements show that the deformations and displacements are continuing to increase during the time, albeit at continuously reduced rate, Figure 3b. This increase has a significant effect on the primary support system and, consequently, on the secondary lining.

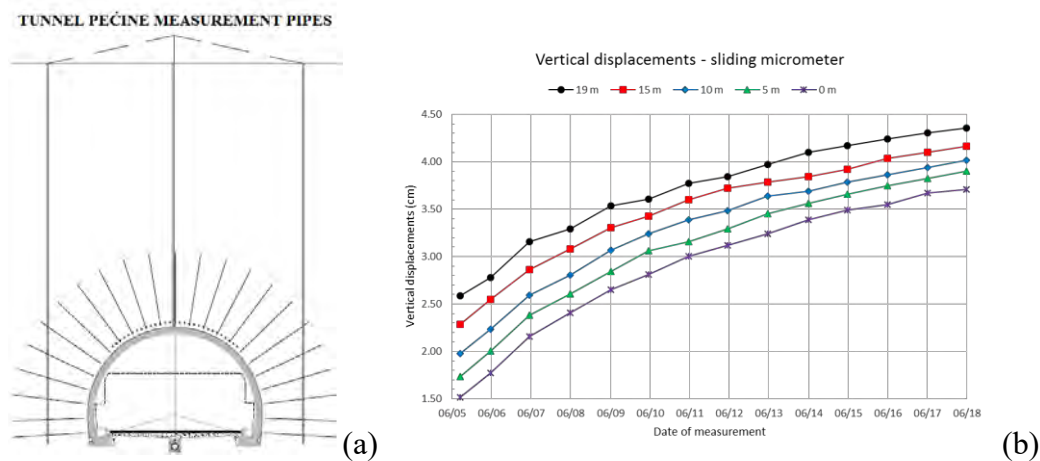


Figure 3. The characteristic monitoring cross section of Pećine tunnel (a), the results of 13 year long monitoring of rock mass vertical displacements

#### 4. Analysis of the long-term development of secondary lining structural cracks

##### 4.1. Development of the long-term behaviour model with application of neural networks

Numerical analysis of long-term behavior of surrounding rock mass is a first step in analysis of long-term development of secondary lining cracks in tunnel. For this purpose, a constitutive model for long-term behavior of rock mass is supported by the implementation of the neural network using back propagation learning algorithm. Since the viscoplastic time-dependent behavior is typical for rock masses, a Burgers-creep viscoplastic constitutive model is selected as appropriate (Guan et al., 2008), Figure 4. This model is characterized by a visco-elasto-plastic deviatoric behavior and an elasto-plastic volumetric behavior, where the visco-elastic and plastic strain-rate components are assumed to act in series. The visco-elastic constitutive law corresponds to a Burgers model (Kelvin cell in series with a Maxwell component), and the plastic constitutive law corresponds to a Hoek-Brown model.

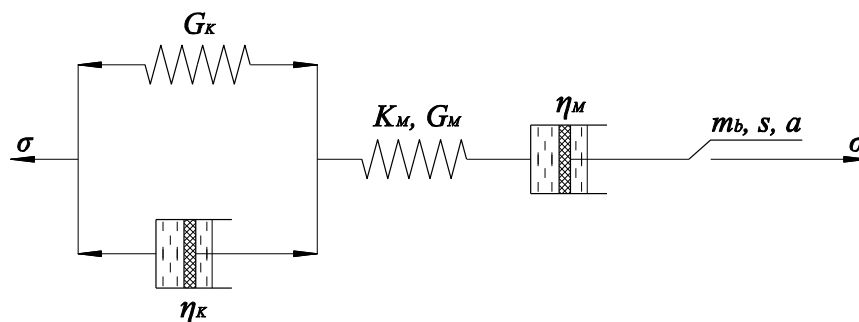


Figure 4. A Burgers-creep viscoplastic model

In order to use this constitutive model in numerical analysis of long-term behaviour of rock mass surrounding tunnel, the 9 input parameters should be defined, including: Elastic bulk modulus,  $K$ ; Hoek-Brown constants,  $m_b, s, a$ ; mass density,  $\rho$ ; Kelvin shear modulus,  $G_K$ ; Kelvin viscosity factor,  $\eta_K$ ; elastic shear modulus,  $G_M$  and Maxwell viscosity factor,  $\eta_M$ . Among these,  $G_K, \eta_K$  and  $\eta_M$  dominantly influence the time-dependent behavior of rock mass and in

same time are most difficult to obtain. Therefore, in order to determine their value, a numerical back-analysis are conducted along with development of custom-made neural network. The neural network, which requires a large amount of data, is a very efficient tool for determination of numerical model input parameters from the long-term monitoring results. The procedure is following:

- 1) a generation of a database where large number ('n') of sets of input rheological parameters ( $G_K$ ,  $\eta_K$  and  $\eta_M$ ) are applied to the numerical simulations with same set-up. These simulations result in 'n' output displacement groups
- 2) the input - output datasets ('n') are then used to train the neural network (NN) using back propagation learning algorithm. After a certain number of training iterations, the post-trained network is expected to approximate the aforementioned numerical simulations.
- 3) the monitoring displacement values are then implemented in trained NN as an input, where the NN output is now defined as the 'most probable set of rheological ( $G_K$ ,  $\eta_K$  and  $\eta_M$ ) parameters'
- 4) the numerical analysis, now having the constitutive model with the most probable set of rheological parameters, are conducted to foresee the behavior of rock mass for long-term period after tunnel construction.

Through the step (4), an increasing trend of rock mass displacement as well as internal force values of primary support elements, can be determined for each year of tunnel's service life. At some point during the service life, due to rock mass creep effect, the internal forces will exceed the primary support element capacity, leading to re-distribution of excessive loads to the secondary lining.

#### *4.2.Evaluation of secondary lining structural crack width*

Usual practice in the secondary lining design takes into consideration series of loading factors (self-weight, equipment weight, temperature change, degradation of primary support, concrete shrinkage etc), but the long-term load increase due to rock mass creep is not considered. Since the secondary lining is not designed to overtake these excessive loads, cracking will occur. Larger excessive loads on lining means larger crack width, which needs to be properly evaluated.

When the rockbolt mobilized internal forces exceed the rock bolt capacity, the excessive portion is transferred to the shotcrete and finally to secondary lining. Same is valid for excessive internal forces of shotcrete, which are transferred to the secondary lining. By considering the numerically obtained values of excessive axial forces (N) and bending moments (M) during long-term period, a time-dependent development of cracks can be evaluated.

By using a M-N interaction, a crack width can be automatically calculated based on the principles given in Eurocode 1992 standard (CEN, 2004). The overall characteristic crack width ( $w_k$ ) is determined as:

$$W_k = \beta \cdot S_{rm} \cdot \varepsilon_{sm} \quad (1)$$

where the  $\beta$  is ratio between characteristic and average crack width,  $S_{m}$  is average crack spacing and  $\varepsilon_{sm}$  is mean steel strain under relevant combination of loads. To calculate these parameters, it is necessary to have an input on concrete class, on longitudinal reinforcement bar diameter and on surface area of longitudinal reinforcement. More details on the calculation is given within the Eurocode 1992.

### 5. The calculation of life-cycle costs for remediation of secondary lining cracks

After determination of long-term crack width propagation in secondary lining of tunnel, it is necessary to implement the results into the cost calculation phase of framework. This phase enables proactive (predictive) maintenance of secondary lining, based on the simple economic assumption that it is better to invest now, in order to prevent structure damage, to save money later, Figure 5. The Figure further explains how time progressively increases costs of the remediation. Thus, it is important to establish a systematic monitoring system of rock mass behavior in time and try to act during the initial i.e. the latent phase (see figure 5), before the crack progression phase has started.

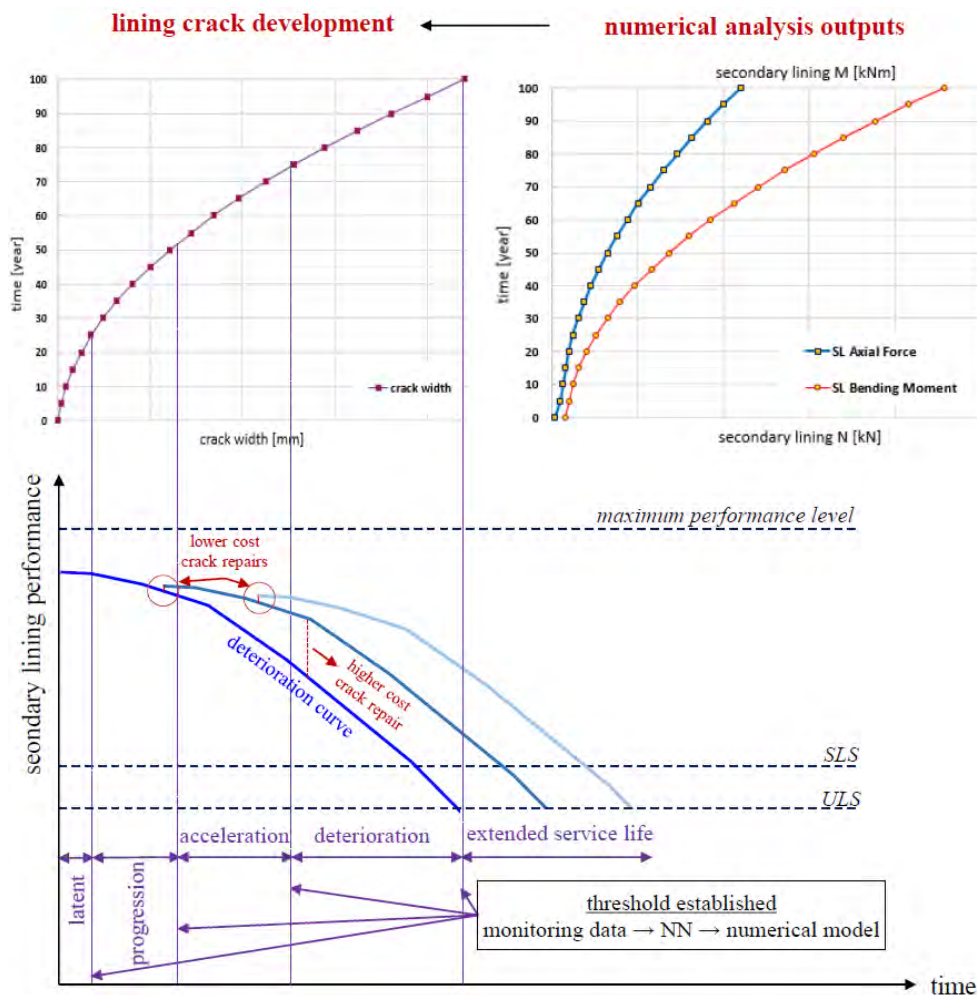


Figure 5. A secondary lining deterioration characteristics based on determined values of crack width

The crack propagation is 'translated' in terms of repair costs using a planning and calculation software GALA, developed in cooperation with academia. The program develops in the direction of integration costs, time and quality, an integral - a holistic system for the

management of construction projects. The custom-made GALA module completely resolves calculation, planning and expenditure related to the repair of secondary lining cracks. The main input for the calculation of remediation costs is the calculated value of the crack width. The GALA uses this input and warns the user about the newly arisen costs by automatically calculating the costs based on the remediation technology suitable for the cracking condition during tunnel service life. This automated system for calculation of costs generates bills of costs and schedule. GALA first suggests the technology options and associates normative of labor (in man hours), material (of remediation) and equipment costs according to the four phases depicted on the Figure 5. Thus, for each of the category of the crack width and the phase threshold, the associated Bill of Quantities (BoQ) is generated. Second, the user selects the technology of remediation which automatically generates the database of needed resources and associated direct costs of remediation. Additionally, the user can pre-set the costs of indirect costs (sourcing from construction site and overhead from permanent organization) and additional costs associated with tunnel temporary shutdown. Third, after calculating the both direct and indirect costs, four different Bills of Costs (BoC) are offered to the user. Finally, based upon the selected BoC, the user is confronted with the timeframe of remediation (represented by a gantt-chart) and the general terms of implementing the technology represented by the BoC. Thus, the automated system determines the width of the crack and provides ready-to-use documents needed for procurement of works.

## 6. Conclusions

In order to overcome the evident issues of reactive, untimely, planning of secondary lining maintenance, the paper proposes a framework, which provides the tunnel managers opportunity for proactive planning. The framework is developed for the structural cracks in secondary lining of tunnels, developed due to secondary lining over loading, as a direct consequence of creep of rock mass surrounding the tunnel. These cracks will eventually endanger both the functionality and safety of tunnels as important assets of infrastructure networks.

The input data for the framework is obtained through the continuous, long-term, in-situ monitoring of the secondary lining and surrounding rock mass. This information is used to feed into the neural network with custom-made architecture, which is then used to give an information on the most probable sets of numerical model inputs. The numerical model calculates the lining internal forces, from where the crack width can be automatically calculated. The monitoring data is continuously used to update the crack development model, in order to determine the crack width propagation rate. In final phase, life-cycle costs are determined using software for cost calculations, where the sole input of crack width gives an detail insight into life-cycle repair costs including man/hour, equipment/hour, material and other costs.

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# Effective Connection of Terrestrial Laser Scanner and Unmanned Aerial Vehicle for as Built Measurement of Buildings

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## **Abstract:**

Many historical but oftentimes also modern building construction it is necessary to reconstruct and these building objects are often characterized by the fact that the as-built documentation isn't accurate, isn't actual or even doesn't exist. The technology of terrestrial laser scanning and aerial photogrammetry with using a drone at present can serve as effective and progressive tools in the area of 3D spatial digitization of buildings and their geometric dimensions. Both technologies have the same result and its detailed 3D representation of a building in a digital environment. This detailed 3D representation of the building project is often called a point cloud. The same result also means that results of both technologies can be connected together. Laser scanners are a great tool for measuring existing buildings but they have the same problem as visual surveys-if you can't see it, you can't scan it. It means that the laser beam from the scanner can't measure a certain part of the surface of the building if this part isn't in the scanner's field of view. One of these parts are for example surfaces of roof structures and therefore the use of unmanned aircraft vehicles (drones) represents an effective solution to this limitation of the laser scanner. Drones can in this case serve as a complementary technology for laser scanning or can replace laser scanning completely. The aim of this paper is to describe the use of these two technologies and as a reference building the Faculty of Civil Engineering, located in Kosice, Slovakia was chosen.

*Keywords: laser scanner, terrestrial laser scanning, unmanned aerial vehicle, aerial photogrammetry, point cloud;*

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## **1. Introduction**

Methods and techniques of recording constructions have an array of possibilities, naturally starting from the simplest manual recordings up to modern technologies which provide options of virtual presentations of parts of a construction and its whole, or of old historical constructions.

Laser scanning and photogrammetry are extensively used to perform for documentation and virtual realization of three-dimensional (3D) models of buildings. The selection of the method that will be used in three-dimensional modelling study depends (Altuntas, 2015) on the scale and shape of the object, and also applicability of the method. Laser scanners are high cost instruments. However, the cameras are low cost instruments. The off-the-shelf cameras are used for taking the photogrammetric images. The camera is imaging the object details by carrying on hand while the laser scanner makes ground based measurement. Laser scanner collect high density spatial data in a short time from the measurement area. On the other hand, image based

3D measurement uses images to create 3D point cloud data. The image matching and the creation of the point cloud can be done automatically.

Photogrammetry has long been used as a tool for collecting three-dimensional (3D) information of cultural heritage objects as well as texture information (Naci, 2007). Photogrammetry (Drones/Quadcopters for Data Collection, 2017) is a technique used in surveying to measure the three dimensional coordinates with the help of photography. The term “photogrammetry” is composed of the words “photo” and “meter” meaning measurements from photographs. Photogrammetry is traditional methods on documentation of historical artefacts (Remondino, 2014; Bosch et al. 2005; Tozand Duran, 2004; Lingua et al., 2003). The 3D coordinates of points on an object surface are determined based on overlapping images with camera position and orientation information known as exterior orientation (Naci, 2007). However the measurement to all details with particular spaces by the photogrammetry require more time and labour. Thus some characteristic points which represent the shape are measured from the images. For such an application of photogrammetry, at least two photographs of the same building are required, as well as the exact distance between two points visible in at least one photograph (Krasic and Pejic, 2014). Basic categories of photogrammetry terrestrial and aerial - follow a criterion of a referential point position. Ground photogrammetry is taken from a point on or near the surface of the ground, and aerial photogrammetry is taken from the air, and in most cases from an airplane, a satellite or a unmanned aerial vehicle (UAV) (Pejic and Krasic, 2012). UAV devices and aerial photogrammetry imaging applications are increasing rapidly (Fintan, 2018). Recent years have seen a significant increase in UAV uses for many applications in the fields of science and engineering (William W. et al. 2019). This is not surprising as using GPS enabled UAVs for aerial surveying is very cost effective in comparison to hiring an aircraft with photogrammetry equipment. Because UAVs are relatively inexpensive, many organisations will have their own UAV fleet, allowing for rapid surveys over large land areas and infrastructure projects where required. With GPS equipped drones, digital cameras and powerful computers, surveys have an accuracy right down to 1 centimeter (Fintan, 2018). On the other hand laser scanning has been extensively used to creating 3D model of cultural heritage for two decades (Altuntas et al., 2014; Akca et al., 2006). Terrestrial laser scanner (TLS) collects high density 3D spatial data from the measurement area in a short time. Some buildings have complex details. All details cannot be measured by TLS since the TLS makes ground based measurement. On the other hand, 3D virtual modelling and realization needs photogrammetric and laser scanning data (Remondino, 2011; Grussenmeyer et al., 2011). Texture data of photogrammetric images are matched with the laser point cloud for creation of 3D virtual model. Creation of 3D virtual model for recording architecture of buildings is a very efficient and quality way of presentation which is possible owing to availability of various modern technologies. That’s why a method of terrestrial laser scanning and aerial photogrammetry is used for collecting data. By using these methods it is possible to create very accurate digital models of constructions and spatial entities. Despite the considerable progress of these technologies, there are still some limitations, which have an effect on the quality of the final 3D model in the form of a point cloud. Even though current laser scanners can produce large point clouds fast and reliably, on the other hand many building objects contain places which the scanner can’t measure, e.g., roof structures. In this situation the final

product can be a problem because the point cloud doesn't contain all spatial information. In the contrary, the digital aerial photogrammetry using UAV drones can provide solution for this limitation (Haala and Alshwabkeh, 2006). Drone adoption by the construction industry is continuously growing as is the development of drones to suit various needs. A recent study identified that 26% of construction professionals are already using or plan to use a drone by 2020. Technological improvements will make drones fly faster for longer and improve footage quality ensuring that drones will soon be used by most construction sites and projects all over the world (ALTI, 2019).

## 2. Methods

The Faculty of Civil Engineering has a simple layout in the L shape with a built-up area of 3150 m<sup>2</sup>, a height of 20 meters and a roof angle of 24°. **The main aim of digital measurement was to measure the exterior of the building completely**, it means, the facade with the roof. **This building can be measured by three methods** and each of them has its own specifics, benefits but also limitations and disadvantages.

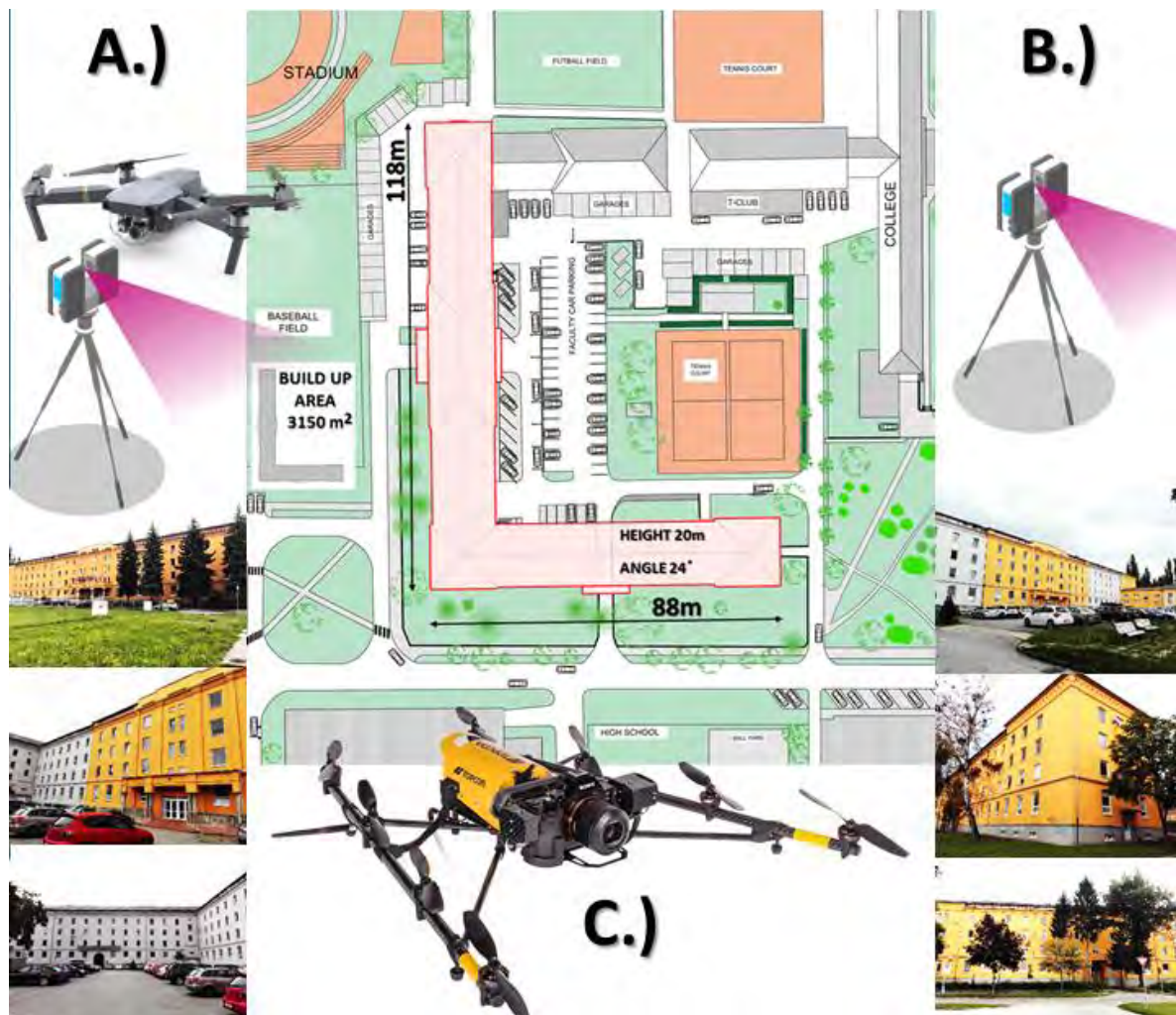


Figure 23. Faculty of Civil Engineering and three methods of spatial digitization using a terrestrial laser scanner and unmanned aerial vehicle "drone" (source: authors)

Digital surveying of the Faculty of Civil Engineering was divided into three methods:

A.) Terrestrial laser scanning/Aerial photogrammetry - parts of the building selected for as built surveying:

**Exterior** – TLS – facade of the building/UAV – roof of the building

B.) Terrestrial laser scanning - parts of the building selected for as built surveying:

**Exterior** – TLS – facade and roof of the building

C.) Aerial photogrammetry - parts of the building selected for as built surveying:

**Exterior** – UAV – facade and roof of the building

A.) Digital as built surveying by terrestrial laser scanning and aerial photogrammetry

For terrestrial laser scanning the laser scanner **FARO Focus 3D X130** was selected. Looking Fig. 2 it can be seen the real positions of the laser scanner (*blue points*), start and end of scanning (*red points*) and direction of scanning around the entire building. The aim was to measure the entire exterior (*with focusing on the facade*) of the building in 1 day. The measurement took place in early October, i.e., the work had to be done by about 6.00 – 6:30 p.m., because at that time it was almost dark in outside. Of course, it would be possible to continue scanning in the dark but one of the criteria was to create a colored point cloud based on panoramic photos that the scanner created during the measurement. **The overall scanning time was from 6:45 a.m. to 6:30 p.m. (approximately 12 hours) and together was created 48 scanner positions.** This number of scan positions is the optimal solution for this and its similar buildings.



Figure 24. Technological process of terrestrial laser scanning/focused on the facade from the building (source: authors)

The DJI MAVICO PRO drone was used to create aerial photographs from the building's roof. Furthermore, a remote control, a DJI GO application and a free online application DroneDeploy were used. As a first step, it was necessary to set up a drone flight plan. This plan may be either automatic (Fig. 3) or manual (Fig. 4), i.e., aerial images can be created in automatic or manual flight mode. **Based on the DroneDeploy application was created in the automatic mode 195 aerial images for 5 minutes with overlap of images 80 %.** Remote control manual flight is a bit harder and time-consuming than automatic mode, but if a pilot has enough experiences with flying, it's not a problem. **The overall flight time of the drone in manual mode was 20 minutes and 107 aerial images were created together. The overall time for data collection from the roof of the building using the drone was 30 minutes, 302 aerial images were created with the resolution of the digital camera 12 megapixels.**

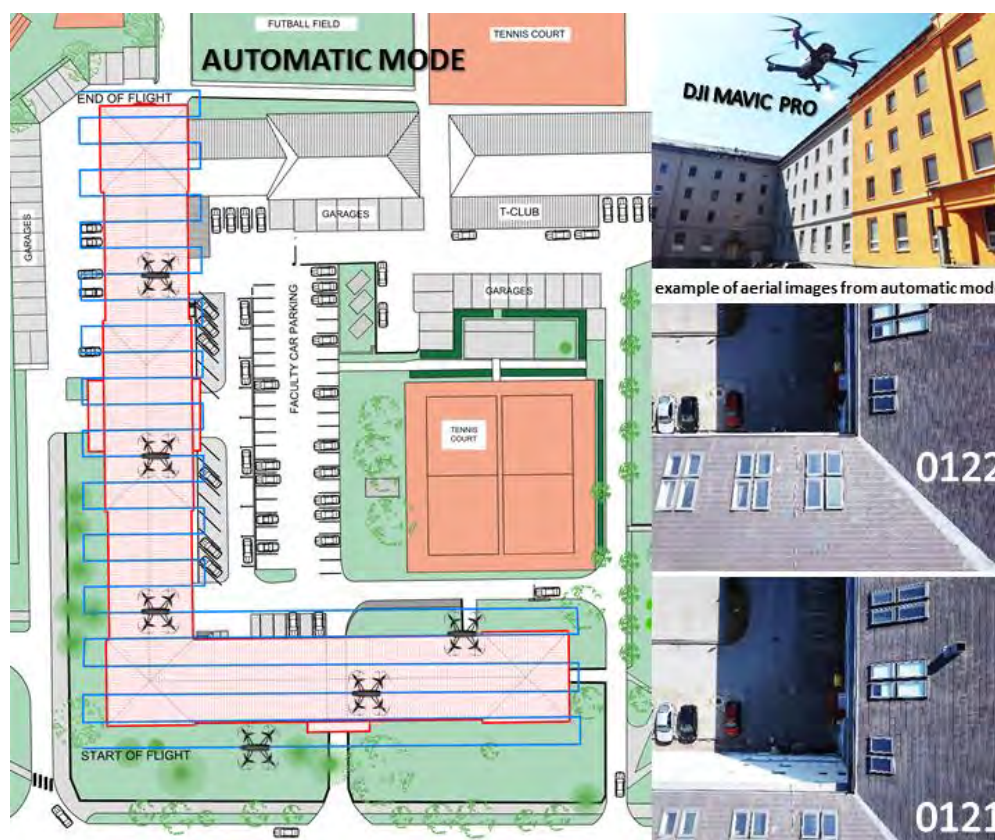


Figure 25. Technological process of aerial photogrammetry/automatic mode (source: authors)

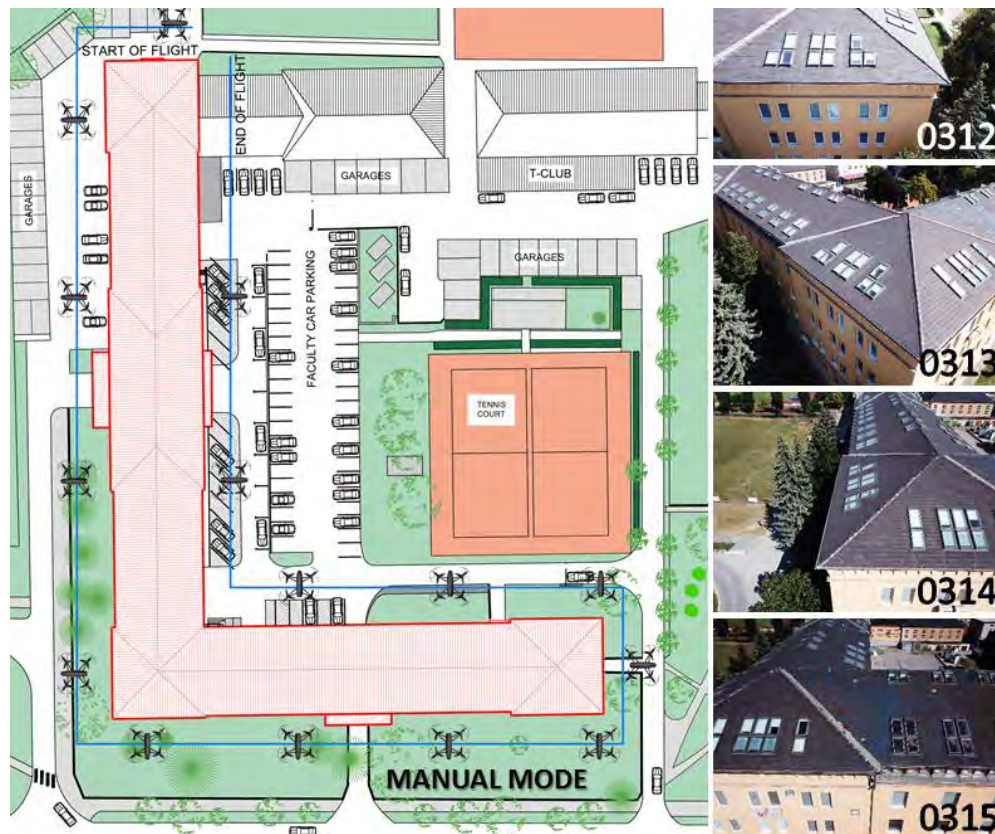


Figure 26. Technological process of aerial photogrammetry/manual mode (source: authors)

The phase of data processing was divided into three stages:

- **the 1<sup>st</sup> stage - creating two point clouds from two technologies:** For data processing of raw data from laser surveying was used the Faro SCENE software. In this software, processes such as registration, deleting of redundant points, color application based on panoramic photos and export of the point cloud in \*E57 format to the Autodesk Recap software were performed. **The overall time of these processes was about 3 hours.** For data processing of raw images from aerial surveying was used the Agisoft Photoscan Professional software. **The overall time for creating the point cloud from 302 aerial photographs was 31 hours** (*sparse point cloud/highest quality/1 hour; dense point cloud/ultrahigh quality/30 hours*). **Of course, lesser quality means less time but also the computer's parameters are decisive for the overall time** (*in this case; processor Intel(R) Core(TM) i7, memory 64 GB, graphic card NVIDIA GeForce GTX 1070*). At the end of this stage, two point clouds were created from two technologies in two different local coordinate systems.
- **the 2<sup>nd</sup> stage – creating a common coordinate system:** The aim of this phase was to create a common coordinate system, i.e., the coordinate system of the point cloud from aerial photographs will adapt (*in the software Agisoft*) to the coordinate system of the point cloud from laser scans. **The overall time for this processes was 1 hour.**
- **the 3<sup>rd</sup> stage - connection of two point clouds into one:** Looking Fig. 5 it can be seen both point clouds in the one common coordinate system. In the last step, it is necessary to connect the point cloud from the facade with the point cloud from the roof



construction. For this connection the CloudCompare software was selected. The overall time to connection two point clouds was only a few minutes and based on the same coordinate systems this connection was automatic.

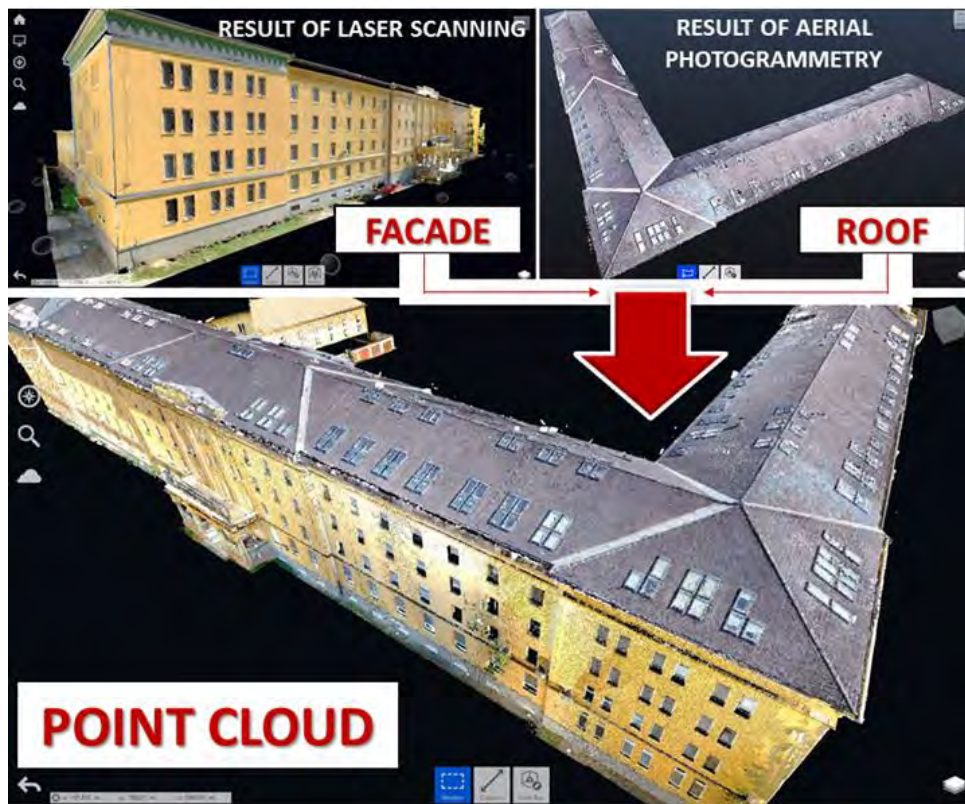
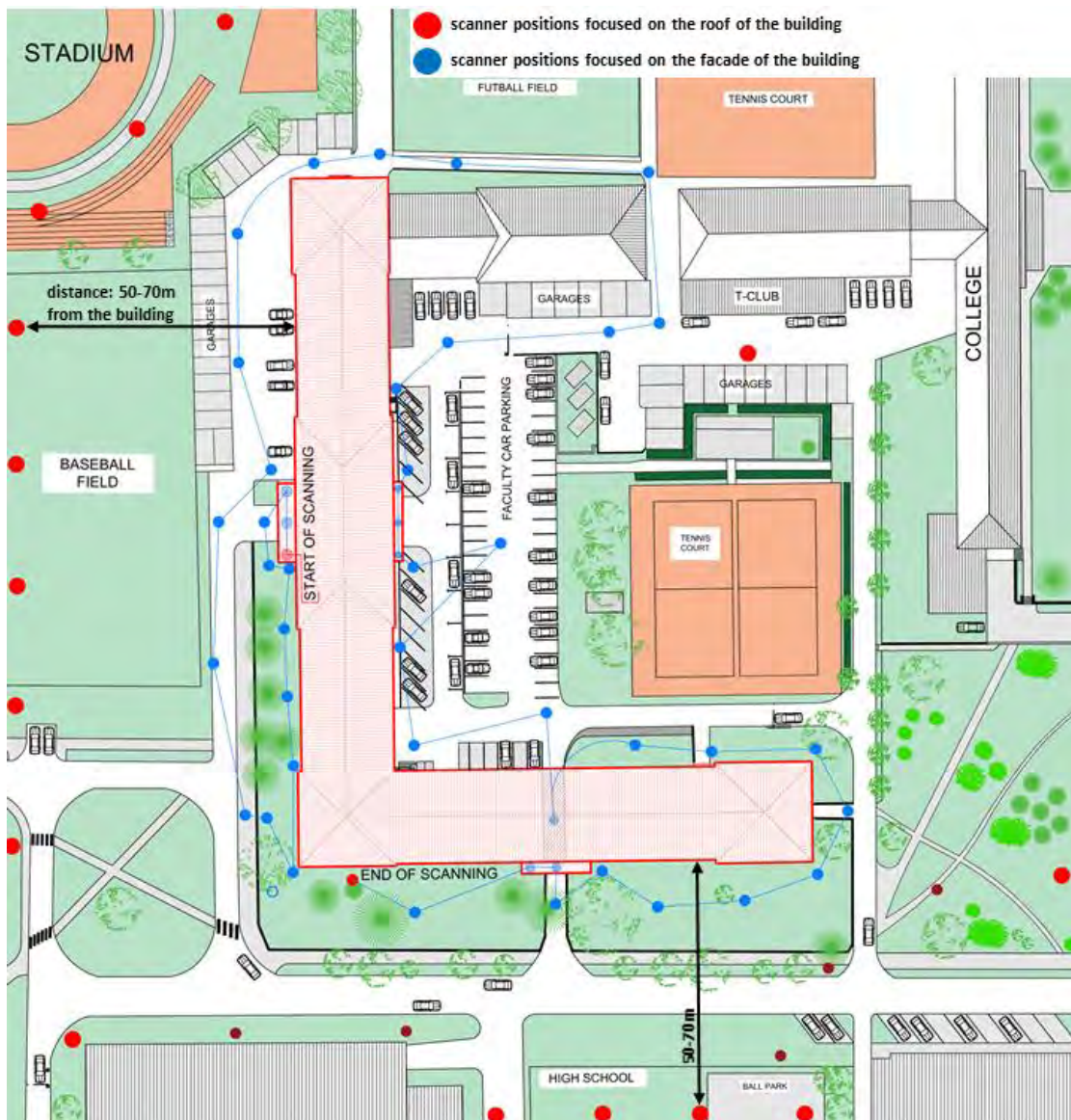


Figure 27. Result of connection two point clouds from two technologies (source: authors)

#### B.) Digital as built surveying only by terrestrial laser scanning

Looking Fig. 6 it can be seen the real positions of the laser scanner (blue points) but also new additional scan positions (red points). Fig. 6 represents only a conceptual design of a situation in which a digital surveying of the exterior of the building was proposed using only the terrestrial laser scanning technology. Red points in the Fig. 6 represent a new additional or extra scans which would need to be created for a surface from the roof structure. These extra scans would have to be created at a distance of 50-70 m from the building. Thanks to this distance it would be possible to measure the largest surface area of the roof structure and this distance is not a problem for the Faro Focus laser scanner because the range of scanning for this scanner is up to 130 m. **The overall data collection time would be 2 days in this case. Expected time for the overall data processing time would be approximately  $\pm 5$  hours** but the quality of the resulting point cloud from the roof surface would certainly be a bit worse than that of aerial photogrammetry using the unmanned aircraft vehicle. This solution is, on the one hand, realistic but on the other hand inefficient in regard to measuring of the building roof.

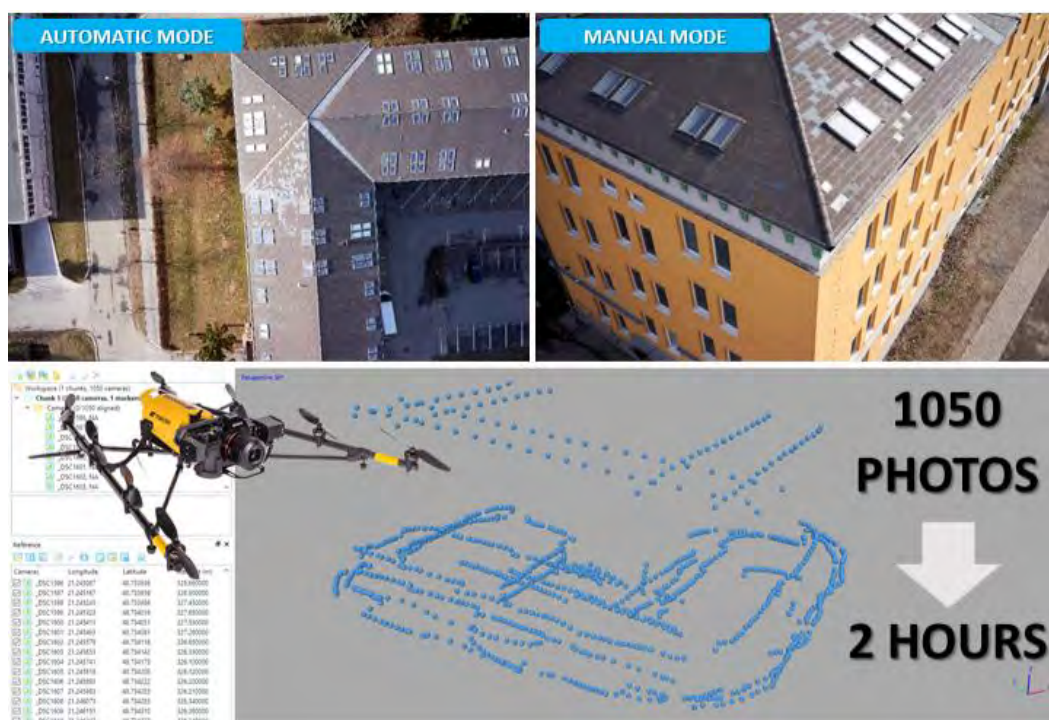


**Figure 28. A conceptual design of a situation in which a digital surveying of the building was proposed using only the terrestrial laser scanning technology (source: authors)**

### C.) Digital as built surveying only by aerial photogrammetry

The aim of this measurement wasn't to measure only the roof structure of the building but also the facade of the building completely. As in the previous study (TLS + UAV), it was also necessary to obtain permission to create aerial images from the Ministry of Defense of the Slovak Republic. The waiting period for permission from the Ministry of Defense of the Slovak Republic lasts about two or three weeks. After creating aerial images in the terrain, it was necessary to send aerial images for assessment again to the Ministry of Defense of the Slovak Republic. The waiting period for assessment from the Ministry of Defense of the Slovak Republic lasts about again two or three weeks. When deciding which of the technologies to use for digital as built surveying, several weeks of waiting time for permission and assessment from the Ministry of Defense of the Slovak Republic can act as a limiting factor in deciding which technology to use for a digital as built surveying of a building object.

For creating of aerial images from the building was choose from the Topcon Company the drone Falcon 8. This type of the drone is possible to classify such as Octocopter (number of rotors 8) by contrast to the drone DJI MAVIC which is classify as a Quadrocopter (number of rotors 4). The disadvantage of this drone (Falcon 8) is its take-off weight (2.8 kg), which has a major impact on **battery life**. The flight conditions for the data collection were not the most ideal because the flight took place in colder weather (about 5 ° C) at the end of February and at a wind speed of about 15 m/s. It was not possible to capture slightly cloudy weather, so there were many shadows on the building's facade, which could not be influenced. These effects meant that one battery lasted only 7 minutes and since the overall flight time was 2 hours, the overall of 10 batteries had to be replaced throughout the overall flight. Also aerial images were created in automatic and manual mode. **The overall flight time was 2 hours and the overall of 1050 aerial images were created with the resolution of the digital camera 36 megapixels.**



**Figure 29. Data collection of aerial photogrammetry by the drone Falcon 8 (source: authors)**

The process of creating aerial images was the same as in the previous case, i.e., as first, aerial images were created in automatic mode where 100 images were created in 3 minutes with 80% overlap between images. After that, aerial images were created in manual mode where the overall of 990 images were created at different heights to capture all the necessary details on the building's facade. The raw aerial images were again processed by the software Agisoft Photoscan Professional and was used the computer with the same parameters as in the previous case. In the previous case 302 aerial images were created and the highest possible point cloud quality was selected. In the previous case was the overall data processing time 31 hours. In this case was created 1050 aerial images, it means, that the overall data processing time would be even greater. **For that reason the medium quality of the point cloud was selected. The overall data processing time was in this case 33 hours (1 day and 9 hours nonstop).** High and ultra-high point cloud quality has not been tested in this case because it is a very time-

consuming task for the computer. The estimated time of ultra-high quality for 1050 aerial images could be up to 1 week. Looking Fig. 8 it can be seen that the final quality of the point cloud from the building's facade is very good.

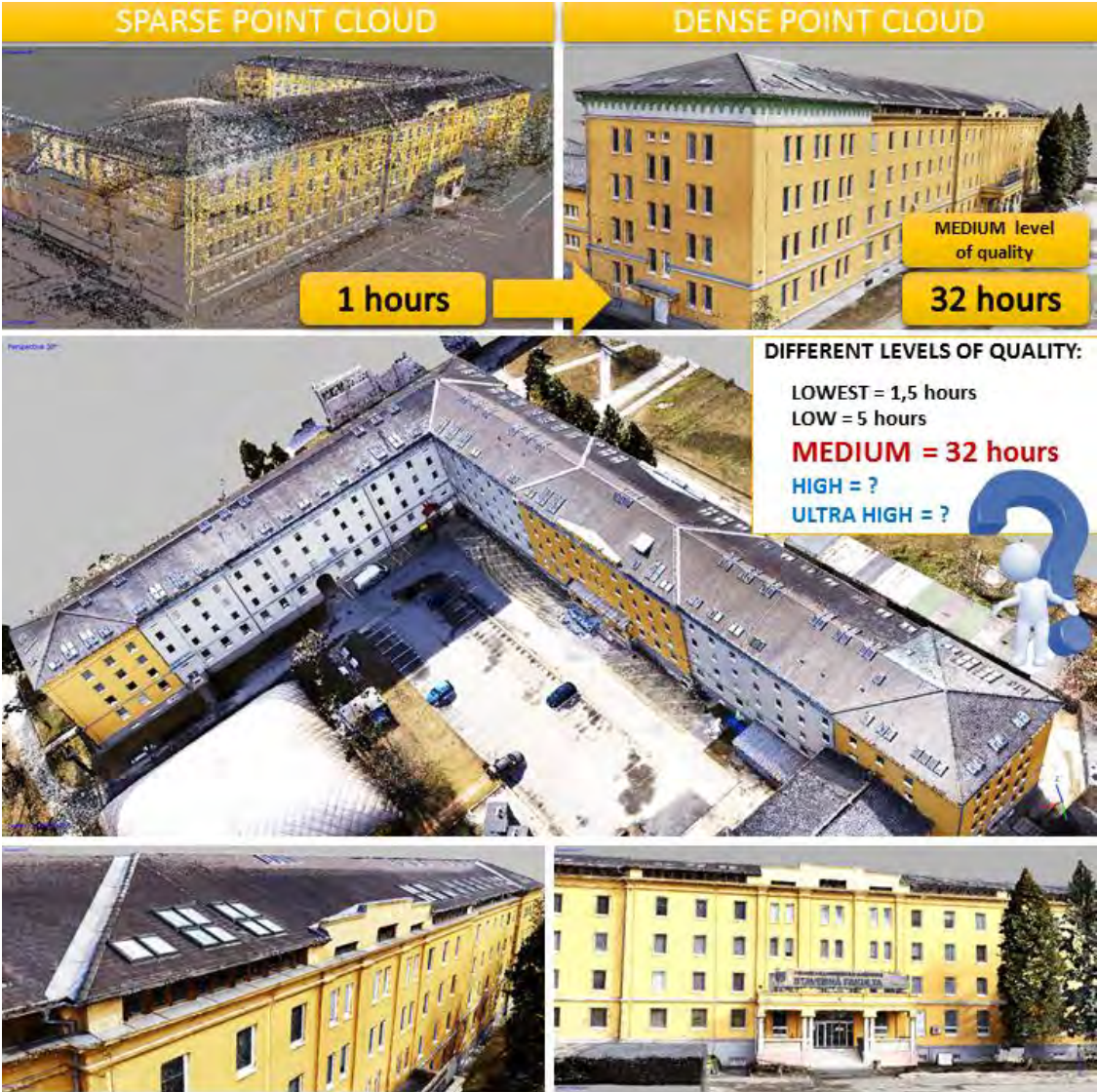










Figure 30. The result of aerial photogrammetry which was focused on the complete exterior of the Faculty of Civil Engineering (source: authors)

### 3. Results

If we compare results of the overall data collection time (Tab. 1) we can see that the aerial photogrammetry is much faster than laser scanning (approx. about 90%). But on the other hand if we compare results of the overall data processing time we can see that the laser scanning is much faster than aerial photogrammetry. But this is only a time parameter and what is more important it is the overall quality and details of the final result (point cloud).


**Table 23. Digital as built surveying of the Faculty of Civil Engineering – results (source: authors)**

Selected part of the building: EXTERIOR		
Methods of digital as built surveying		
Terrestrial Laser Scanning (facade) Aerial Photogrammetry (roof)	Terrestrial Laser Scanning (facade/roof)	Aerial Photogrammetry (facade/roof)
<b>DATA COLLECTION</b>		
<p>1 day TLS (approx. 12 hours)</p> <p>1 day UAV (30 minutes)</p> <p> </p>	<p>1 day TLS (focusing on the roof of the building)</p> <p>1 day TLS (focusing on the facade of the building)</p> <p></p>	<p>2 hours (focusing on the roof and the facade of the building)</p> <p></p>
<b>DATA PROCESSING</b>		
<p>35 HOURS</p> <p>Note: 3 hours / data processing of terrestrial laser scanning</p> <p></p> <p>31 hours / data processing of aerial photogrammetry</p> <p>SPARSE POINT CLOUD!</p> <p>Highest quality – 1 hour</p> <p>DENSE POINT CLOUD!</p> <p>Ultrahigh quality – 30 hours</p> <p>Worse quality means less time!</p> <p></p>	<p>± 5 HOURS</p> <p>Note: estimated time</p> <p></p>	<p>33 HOURS</p> <p>Note: 33 hours / data processing of aerial photogrammetry</p> <p>SPARSE POINT CLOUD!</p> <p>High quality – 1 hour</p> <p>DENSE POINT CLOUD!</p> <p>Lowest quality – 1.5 hours</p> <p>Low quality – 5 hours</p> <p>Medium quality – 32 hours</p> <p>High quality - ?</p> <p>Ultrahigh quality – estimated time 1 week or more</p> <p>Better quality means more time!</p> <p></p>

1 hours / creating a common coordinate system		
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Table 2 contains all the important advantages and disadvantages of both technologies that have occurred in all three case studies.

**Table 24. Advantages and disadvantages of both technologies in this case study (source: authors)**

Selected part of the building: EXTERIOR		
Methods of digital as built surveying		
Terrestrial Laser Scanning (facade) Aerial Photogrammetry (roof)	Terrestrial Laser Scanning (facade/roof)	Aerial Photogrammetry (facade/roof)
<b>ADVANTAGES</b>		
 <p>The combination of the terrestrial laser scanner and the drone is an effective solution for any type of building construction. In this case the drone served us only as a complementary technology to the laser scanner,  Price of the drone (DJI MAVIC PRO) in this case – approx. 1 500 €  Terrestrial laser scanning doesn't require permission from the Ministry of Defence of the Slovak Republic,  Terrestrial laser scanning – weather conditions - it requires less weather requirements than working with a drone,  Battery life – in this case the weight of the drone DJI MAVIC PRO was only 0,740 kg and for that reason the life of the one battery was approx. 30 minutes. Therefore 1 battery was used for the overall data collection over 30 minutes,  Speed of the data collection using the drone (approx. 90% faster than laser scanning) if we are talking about measuring of the roof construction of the building,  Using the drone it is possible to measure places that may be dangerous for the scanner operator,  The overall data processing phase of laser scans is a much faster in contrast to the data processing of aerial images,</p>		
<p>Using the laser scanner it was possible to measure all important spatial information from the exterior of the Faculty of Civil Engineering. The facade of the building was measured in high spatial details but for the roof of the building wasn't possible to create a point cloud quality like using aerial images using the drone. Of course the surface of the roof would be measured but only in the low quality,  Terrestrial laser scanning doesn't require permission from the Ministry of Defence of the Slovak Republic,  Terrestrial laser scanning – weather conditions - it requires less weather requirements than working with a drone,  The overall data processing phase of laser scans is a much faster in contrast to the data processing of aerial images,</p>	<p>Using the drone it was possible to measure all important spatial information from the exterior of the Faculty of Civil Engineering. The roof and the facade of the building were measured in high spatial details,  Resolution of the digital camera – 36 megapixels - with this digital camera it was possible to create high quality of aerial images/photos and for that reason it was possible to create high detail of the dense point cloud,  Speed of the data collection (approx. 90% faster than laser scanning),  It was possible to create an automatic drone flight with automatic aerial image creation - only if the camera is rotated vertically to the ground,  Drone handling is faster and easier than with a laser scanner,  Using the drone it is possible to measure places that may be dangerous for the scanner operator,</p>	

## DISADVANTAGES



<p>Price of the laser scanner – approx. 30 000€ + additional hardware devices and software, Aerial photogrammetry - weather conditions – wind speed, low temperature, cloud amount, shadows, dazzling sunshine, Price of the software Faro Scene approx. 5 000€, Resolution of the digital camera – 12 megapixels - for digital mapping of buildings using a drone it is preferable to use digital cameras with better resolution, The disadvantage of terrestrial laser scanning is the overall data collection time in contrast to aerial photogrammetry and the use of the drone, Handling of a terrestrial laser scanner is more difficult than with a drone, Aerial images are demanding of the process of data processing - factors - the number and quality of aerial images, software used, computer capacity and its parameters, Danger of attacking the drone by birds, Price of the software Agisoft Photoscan Professional approx. 3 500€, **Permission of the Ministry of Defence.</p>	<p>The disadvantage of terrestrial laser scanning is the overall data collection time in contrast to aerial photogrammetry and the use of the drone, Price of the laser scanner – approx. 30 000€ + additional hardware devices and software, Most roof constructions represent a limitation for terrestrial laser scanning, Price of the software Faro Scene approx. 5 000€, Handling of a terrestrial laser scanner is more difficult than with a drone.</p>	<p>Weather conditions – wind speed, low temperature, cloud amount, shadows, dazzling sunshine, Danger of attacking the drone by birds, Battery life – in this case the weight of the drone Falcon 8 was approx. 2.8 kg and for that reason the life of the one battery was only 7 minutes. Therefore 10 batteries were required for the overall data collection over two hours, Aerial images are demanding of the process of data processing - factors - the number and quality of aerial images, software used, computer capacity and its parameters, In the area of measuring a certain types of buildings the drone and the principle of aerial photogrammetry can replace technology of terrestrial laser scanning completely – if we are talking only about measuring of an <i>exterior</i> of some building, Price of the drone – approx. 40 000€ Price of the software Agisoft Photoscan Professional approx. 3 500€ **Permission of the Ministry of Defence.</p>
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\*\*Note: In the Slovak Republic all aerial images/photos that have been created from unmanned aerial vehicle (UAV) and which contain the metadata (GPS coordinates, longitude, latitude, height, yaw, pitch, roll, etc.) require permission from the Ministry of Defence. Waiting period was in the both cases approx. 3 weeks. After taking aerial images it was necessary to send the aerial images back to the Ministry of Defence and wait two or more weeks to overall reviewing of aerial images. The overall waiting period can be approx. 1 month or more and this waiting period is disadvantage for this technology

## 4. Discussion/Conclusion

The aim of this paper was to describe the use of terrestrial laser scanning technology and aerial photogrammetry on a reference building, where the Faculty of Civil Engineering, located in Kosice, Slovakia was chosen. Both technologies have a lot of benefits in the area of digitizing of exist buildings but also several limitations. This reference building was measured by three methods. The first method was combination of the terrestrial laser scanning (TLS) technology and aerial photogrammetry (AP) where the main objective of TLS was to measure only the facade of the building and the main objective of AP was to measure only the roof of the building. The main aim of the second method was to use only TLS technology for the complete measurement of the exterior of the building and the main aim of the third method was to use only AP technology. When comparing the results, it was shown that the use of an unmanned aerial vehicle to measurement of the exterior of a building is approximately 90% faster than

using a terrestrial laser scanner. But on the other hand if we compare results of the overall data processing time we can see that the laser scanning is much faster than aerial photogrammetry. Some buildings are better measured using a laser scanner and some using a drone. For this case study and for the Faculty of Civil Engineering the best choice was to use technology of aerial photogrammetry by a drone. There is no need to look differences between these technologies or say which technology is better and which is worse. The better way is to look benefits and abilities of both technologies and connect them together because the combination of these two technologies creates a very powerful tool for digitizing in the area of building construction.

### **Acknowledgments**

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# Application of Smart Systems for Real Time Monitoring of Ready Mixed Concrete Delivery

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## Abstract:

This paper develops and explores the application of smart systems for real time monitoring of the delivery of ready mixed concrete (RMC) made by the commercial batching plants in India. The steady increase in urban infrastructure development, commercial and residential development will support the big demand and usage of RMC in major urban centers in Gujarat in the age to come. The quality management and observance of concrete is commencing to increase attention by specialist managers in construction. Meanwhile, Metropolitan area typically takes on the one plant multi-site RMC production and supply organization. Hence, more systematic and innovative technologies for real-time tracking of truck mixer operation and monitoring RMC delivery are required, to improve the status quo of managing RMC delivery logistics. The availability of location awareness information was keyed out to assist real-time decision making, provide more control over construction processes, and improve productivity and guard. Consequently, to adapt to the cornfield requirements for monitoring RMC operations an integrated smart navigation system is conceptualized and framed in this paper.

*Keywords: smart systems; real time monitoring; ready mixed concrete (RMC); integrated navigation system*

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## 1. Introduction

Ready-Mixed Concrete (IS: 4926-2003) as “Concrete mixed in a stationary mixer in a central batching and mixing plant or in a truck mixer and supplied in the fresh condition to the purchaser either at the site or into the purchaser’s vehicles.”

The Ready Mixed Concrete business in India is in its babyhood. For instance, 70% of Cement produced in a developed country like Japan. Here in India, Ready Mixed Concrete business uses around 2% of total cement production (Makwana and Pitroda, 2013). Since construction has been an essential index of economic development, the government agencies started to build considerable infrastructure to boost the construction industry. The construction industry needs a number of raw materials, Ready Mixed Concrete (RMC) is the indispensable raw material for construction.

Ready mixed concrete is manufactured in a RMC factory, and the jobsites order the RMC according to the design. Nevertheless, the dispatch in RMC factories, at present, is still operated by experience and radioing. RMC factory generally needs to dispatch RMC to 5 to 10 work sites per day, and large RMC factories need to dispatch too much more work sites. Moreover, sometimes there are too many trucks in a work site, and the dispatch becomes a disorder easily.

As a consequence, not only the progress of the structure but also the quality of RMC would be impressed.

The research is to develop a real-time monitoring platform of RMC delivery based on automated and reliable methods so as to realize: (1) real-time locating the RMC truck-mixer on the move between a batch plant and construction sites; (2) recording the event times of the RMC deliveries for modeling analysis leading up to optimized management strategies; (3) enhancing the reliability and convenience of the communication between the truck-mixer drivers and the control center via the vehicle-borne positioning and communication units.

To facilitate the monitoring of vehicles, materials and labor in construction, many previous research applied quantitative methods to perform orbital tracking and information aggregation. (Jaselskis et. al, 1995) described potential applications of the radio frequency identification tags (RFID) technology in the construction industry. For example, RFID allows the identification of construction vehicles along with the materials being conveyed as they run through electronic check points. In parliamentary law to fulfill the practical requirements, and to validate the usefulness of emerging technologies for monitoring RMC delivery an integrated navigation system, based on Global Positioning System (GPS) /Dead Reckoning (DR) /Bluetooth Beacon (BB) and Global System for Mobile Communication (GSM) technologies, is developed and its applications described in this report. The present paper first overviews the monitoring system plan with respect to (1) integrated navigation technology, (2) event time collection and (3) wireless data communication.

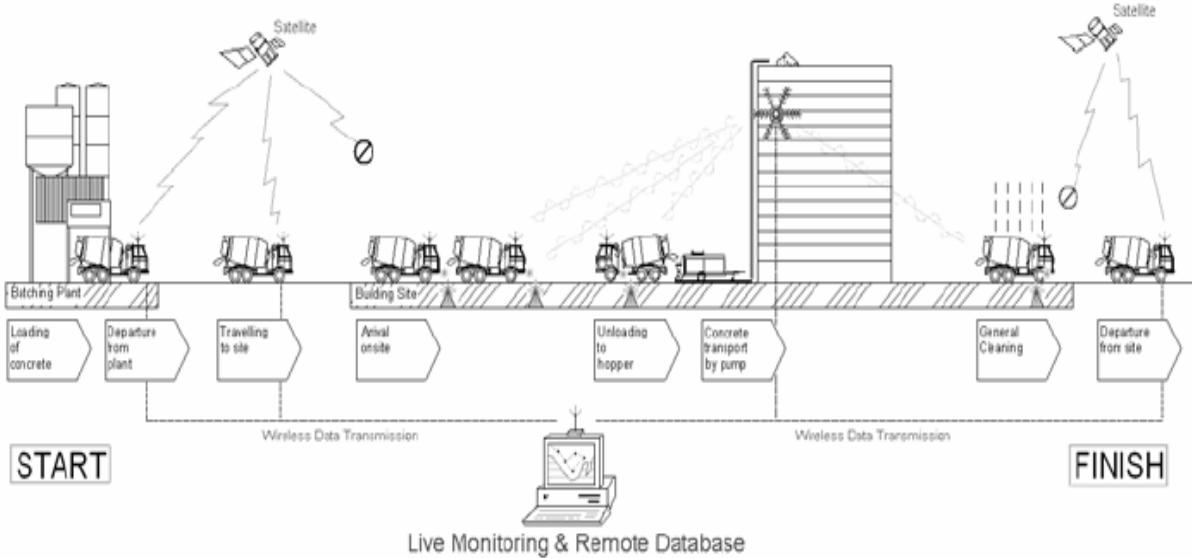


Fig. 1. Process of RMC delivery with truck-mixer

## 2. Methodology

In order to meet the practical requirements, and to validate the usefulness of emerging technologies for monitoring RMC delivery an integrated navigation system, based on Global Positioning System (GPS)/Dead Reckoning (DR)/Bluetooth Beacon (BB) and Global System for Mobile Communication (GSM) technologies. An array of technological tools is offered to handle land vehicle positioning and navigation. These comprises of GPS, Dead Reckoning, Radio Beacon and so on. The integrative use of data from GPS, dead reckoning and Bluetooth Beacon is considered a cost-effective solution to RMC truck-mixer positioning and tracking.

### 2.1. Global Positioning System (GPS)

GPS is a global navigation satellite system, which has twenty-four satellites distributed uniformly in six orbitals at approximately 20,200km above the earth. All the satellites transmit signals on two frequencies called L1 at 1575.42 MHz and L2 at 1227.60MHz (Navon and Goldschmidt, 2003). GPS positioning technique requires at least three satellites in view in order to fix the horizontal position of receiver or at least four satellites in view to enable the determination of the 3D position and time at a user's location (Lu et. al, 2006).

A GPS receiver calculates its position by taking into consideration the signals sent by GPS satellites. The receiver measures the transit time of each message and compute the distance to each satellite. Geometric trilateration of the satellites is used to determine the receiver's location.

GPS has been largely deployed in navigation and surveying applications because of its relative low cost and accuracy in a relatively open area where at least three satellites are available. However, positioning based on GPS alone suffers from signal masking and multipath error in dense urban areas, streets lined with trees; in a tunnel and a building construction site (Lu et. al, 2006).

GPS has been widely employed in vehicle navigation because to its high accuracy and cost-efficiency. Selective Availability (SA) restrictions on 1 May 2000 (Ochieng and Sauer, 2002). To obtain the positioning information of a fix, signals from a minimum of four satellites are needed. To achieve accurate positioning of truck-mixers with GPS alone in the highly dense urban areas and harsh construction sites is difficult due to satellite masking and serious multipath errors from high-rise buildings and the enclosed environment of a building site under construction. (so-called urban canyons areas). A recent study to characterize the performance of GPS in a typical urban area of Hong Kong Island showed that only around 50% of the test area is receptive of GPS signals (Lu et. al, 2007). Moreover, for those accessible control points, the positioning error with GPS is found to be significantly large, over 40% of points greater than 20 m and 9% of points greater than 100m.

### 2.2. Telecommunication Satellite Positioning Systems (TSPS)

Other satellite positioning systems rely on signals from telecommunication satellites that report vehicle locations within 300 m (1,000 ft) of true locations; this is sufficiently precise for many applications. The same satellites are used for both communication and positioning. Such

systems have become very popular with commercial long distance motor carriers (Naresh and Jahren, 1997).

### *2.3 Global System for Mobile Communication and General Packed Radio Service (GSM & GPRS)*

Real time data communication from the truck-mixer and the Control Center is vital to monitoring the motion and status of the RMC truck-mixer. Two-way radio supported speech communication has been largely used due to economy in operation and flexibility in system's configuration. However, radio waves traverse only a limited range, which is inadequate for covering truck-mixers' operations in a metropolitan area. Standard cellular phones communication based on GSM/GPRS (General Packed Radio service) network can overcome the range limitation of radio communication, also such text-based communication systems present many advantages over voice-based system, for example, the text message could be time stamped, queued, easily interpreted without error (Naresh and Jahren, 1997).

### *2.4. Signaling Systems*

Programmable units are available that use existing radio systems to transmit data signals. These data signals represent standard messages that would otherwise be transmitted by voice. Replacement of voice communication by data signals conserves air time. However, these systems cannot locate a vehicle unless location can be inferred from incoming signals. An example of such a system is manufactured by Sigtone Inc. (Winter Park, Fla.). They also manufacture specially designed systems for concrete ready-mix operations. The required hardware includes: (1) mobile reporting units (reporter) mounted on the dashboard of a truck; and (2) a base control unit attached to a microcomputer that is operated by the dispatcher. The base control unit is a communications controller with software that interfaces to the current base radio. The reporter has a keypad with standard messages. For example, a concrete transit mix truck can have keys for (1) loading; (2) transit; (3) leaving and arriving at the plant and job site; (4) pouring; and (5) washing (Naresh and Jahren, 1997). Drivers report status by pressing buttons instead of talking [see Fig. 3(a)]. Status exports can be transmitted in one-sixth of a second, freeing the channel for voice messages. After the status is transmitted to the dispatcher and acknowledged, the LED above the status button will light up. The reports are retained by the computer so dispatchers may read them at their convenience. The reporter will retransmit the status automatically if an acknowledgment is not received.

Status reports can be queued, allowing vehicle drivers to press more than one key at a time. If the status keys are pressed out of order, a warning alert will sound and the status will not be transmitted. If the dispatcher wishes to contact a vehicle, the mobile ID number is keyed in and a message alert (beeping audible and flashing LED) is transmitted to the driver.

The dispatcher may transmit a standard message by pressing a computer function key. If the message is nonstandard, or if a clarification is necessary, voice communication may be used. The mobile unit can hold status calls automatically and send them when the radio channel is not busy; this allows the driver to press the status key immediately without waiting for the radio to clear. The dispatcher's computer display shows the current user of the radio channel and a

record of the status reports received from the mobile units [Fig. 3 (b)]. The base control unit can hold incoming reports until the dispatcher is ready to read them. All status reports are recorded with a time stamp. The computer also stores files containing information necessary for normal operation that can be accessed with a few keystrokes. These files contain addresses, phone numbers, emergency procedures, staff information, operation history, and general help information. There is no added expense for communication links because the signal system uses existing radio links. The cost of a typical base station is \$5,000 and the cost of a typical mobile unit is \$700 (Naresh and Jahren, 1997).

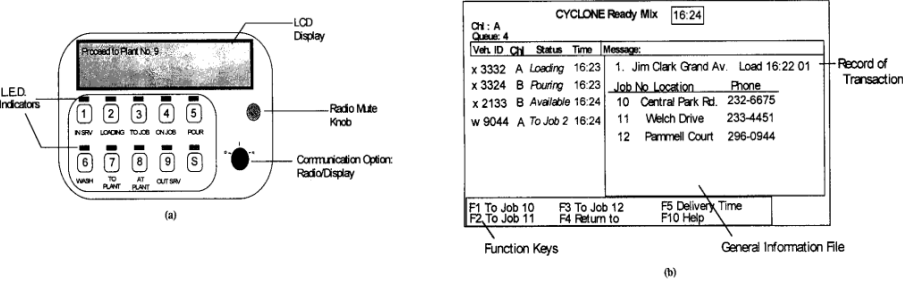


Fig. 1 Signaling System: (a) Reporter Located In Track Cab; (b) Dispatcher's Computer Display

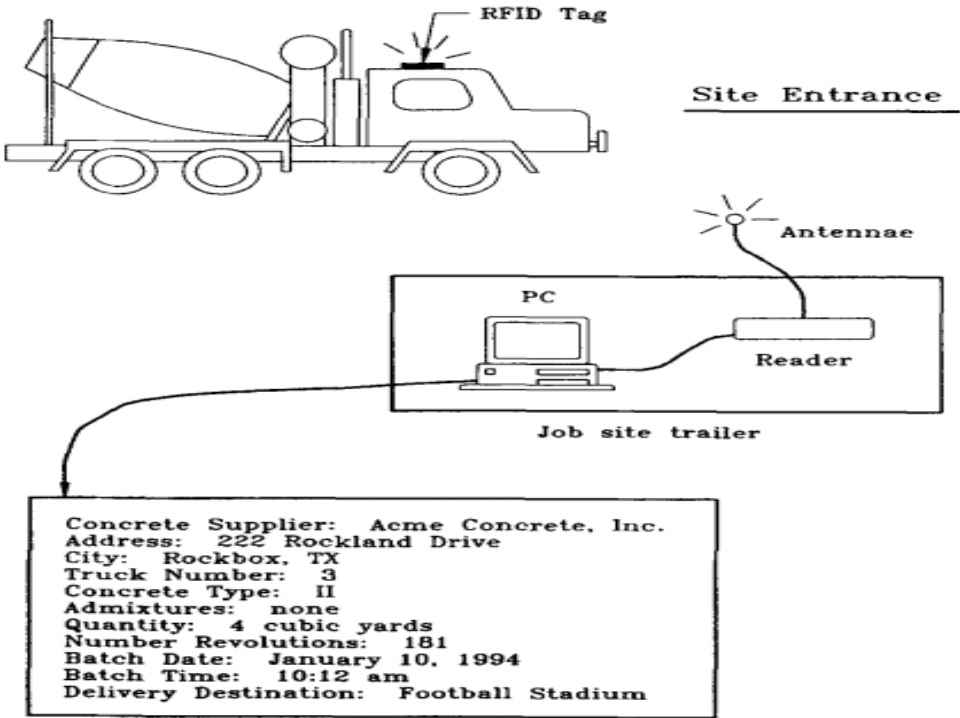


Fig. 3 RFID application in Truck-Mixer

2.5. Radio Frequency Identification (RFID)

This technology is presently employed in many applications outside the infrastructure industry as tracking intermodal freight containers and railroad cars and gathering toll taxes.

(Jaselskis et. al, 1995) provide a description of RFID technology and potential applications in the construction industry. RFID allows users to identify vehicles as they pass electronic check points and can be used as a tracking tool.

RFID systems have the lowest cost per vehicle. The vehicle mounted RFID tags are rugged and require little maintenance. However, the location of a vehicle can only be determined when the vehicle passes a reader and no communication capability is provided. Therefore, this technology is most useful for situations where a large number of trucks must pass bottleneck locations where the tags may be read. The gate of an aggregate, concrete, or asphalt plant can serve as such a bottleneck. This makes RFID an attractive technology for vehicles that service such plants, especially if the size of the fleet is large (Naresh and Jahren, 1997).

RFID system is composed of tags, which carry data in suitable transponders and readers, which decode the data from the tag. RFID tags can either be active or passive depending on source of power. Active tags are battery powered while passive tags are powered by the energy field of the reader. RFID technology overcomes the limitations of barcodes. RFID tags do not require line of sight before they are read, they can be read at a longer range, they are rugged and can survive harsh environment and data on RFID tags are rewritable.

**Table 25 Comparing different RFID frequencies and capabilities**

Generic Band Name	Frequency Range	Typical Application Range		Comment
		Read-Only	Read/Write	
Low Frequency	120– 135KHz	Up to 2m	Few Centimetres	Short range inductive applications
High Frequency	13.56 MHz	Up to 1m	Up to 0.5m	Worldwide common frequency, Smartcards and Labels.
Ultrahigh Frequency	433 MHz 860–960 MHz	Tens m Up to 5m	Few m Up to 0.5m	Active low power tags Band with major supply chain development activity
Microwave	2450 MHz	Upto 10m	Up to 1m	Active tag technology gives range and fast data rates

### *2.6. Inertial Navigation System (INS)*

Inertial Navigation System is a system of devices that estimate the current position of a vehicle by projecting the past courses steered and speeds over ground from a known past position i.e. the direction of travel and starting position must be known to estimate the present position. This technique is called ‘Dead Reckoning’ (DR) (Lu et. al, 2003). The system works with two or more sensors that measure the heading and displacement of the vehicle. The changing rate of vehicle’s heading orientation is gauged with gyroscope and the distance travelled is measured with the odometer of the vehicle. Vehicle navigation system usually involves the integration of GPS and INS so that each can provide for the short coming of the other. GPS becomes unavailable in urban areas or construction sites where there are tall buildings due to blockage of signals. Therefore, to ensure accurate and reliable positioning, virtually all modern land vehicle navigation systems integrate two or more complimentary

positioning technologies to provide vehicles position, velocity and heading information in a seamless fashion (Papadoglou and Stipidis, 2001).

DR systems can be self-contained and the functionality of the speed sensors requires no additional equipment in extracting distance and timing from the DR tracking records (Lu et. al, 2003). DR supplants GPS whenever the GPS is unavailable but DR suffers drift error after a prolonged GPS outage i.e. the reading drifts away from the actual travel path of the vehicle. Therefore, DR is not suitable where accurate positioning is required over extended period of time.

**Table 26 Strengths and Weaknesses of Different Modes of Tracking Systems**

System	Strengths	Weaknesses
Wireless sensors network	<p>Low power consumption resulting in longer battery life</p> <p>Self-organising in maintaining transmission when tags are taken or added to the network</p> <p>Suitable for long range communication up to 100 meters</p> <p>Sensing of ambient conditions such as temperature and humidity</p> <p>Combination of both tracking and localisation functionalities</p>	<p>Multipath error due to reflection of signals by physical obstruction</p> <p>Signal strength fluctuation due to movement of transmitter and receiver</p> <p>Signal shadowing due to physical obstruction</p> <p>Suitable only for applications requiring low data rate</p>
Radio frequency identification device	<p>Suitable for applications requiring both high and low data rate</p> <p>Cheaper tags compared to sensor tags</p> <p>Does not require network infrastructure</p>	<p>High power consumption compared to wireless sensors</p> <p>Short transmission range up to 3 meters</p>
Global positioning system	<p>Accurately tracks locations in an outdoor environment</p> <p>Sufficiently flexible to combine with other technologies such as RFID</p>	<p>Inaccurate positioning at close proximity</p> <p>GPS receivers are highly expensive</p> <p>Multipath error due to physical obstruction</p> <p>Not suitable for indoor application</p>
Dead reckoning (DR)	<p>No signal masking or outage like GPS</p>	<p>Distorted positioning data with increase in time and distance of tracking</p>
Geographical information system	<p>Flexible integration with GPS to provide efficient tracking and positioning functionality</p> <p>Provision of visual interpretation of spatial data integrated with internet</p>	<p>Stand-alone application is limited to map generation only</p>



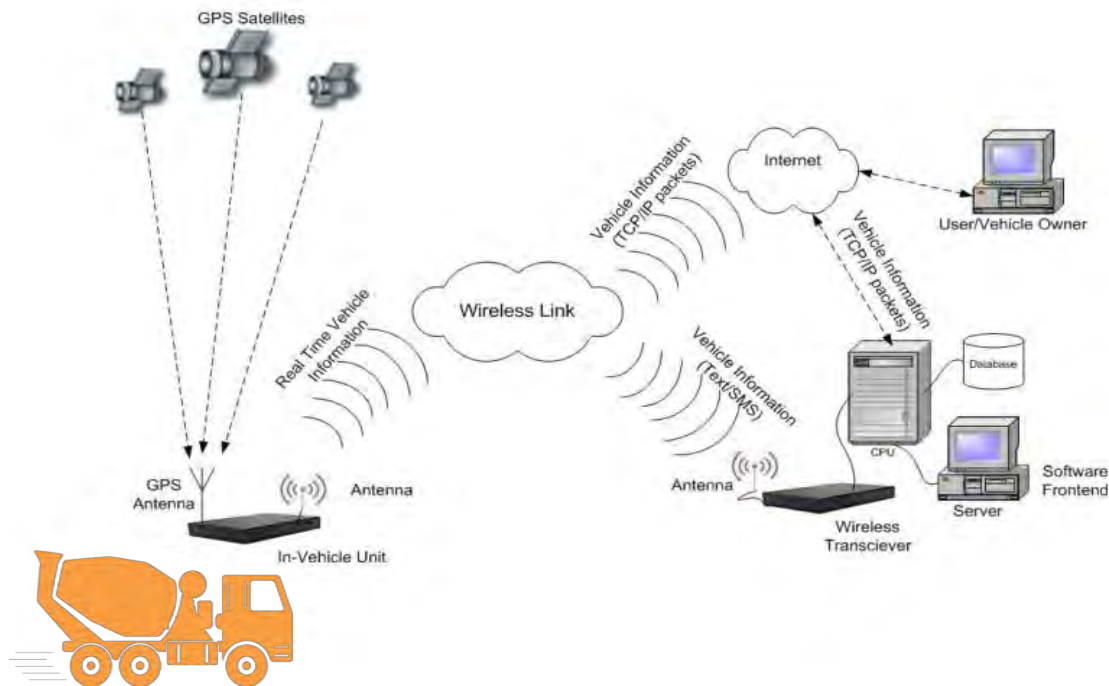


Fig. 4 Automatic Truck-mixer location system (ATL)

### 3. Results and Model Development

A system for automated reporting of the status of a ready mixed slurry material mixer truck, including the status of events in a sequence of events that the truck undergoes in a delivery of the material to a remote location, for system users including dispatchers and managers using a wireless network. The automated reporting system comprises, on board the truck, at least one sensor for detecting an event in the sequence of events that the truck undergoes in the delivery of the material, and a computer apparatus for automatically receiving an input from the sensor, and for transmitting data denoting the detected event to the remote location over the wireless network.

ATL systems aid in determining the geographic positioning information of vehicles and poor, such as dead reckoning, i.e. inertial navigation, active RFID systems or cooperative RTLS systems. After accumulating positioning information, it is transmitted using some kind of telemetry or wireless communications systems. GSM is the most popularly used service for this purpose. In this paper, an ATL system using GPS for positioning information and GSM/GPRS for information transmission has been developed. The design and implementation of the system includes acquisition and transmission of truck-mixer's location data in conjunction with ignition and doors status data to the tracking server. Additionally, system also provides a web-based interface to display all transmitted information to end user along with location of truck-mixer on a map. This system comprises of a "Remote Tracking Server (TS)" and a hardware device known as "In Vehicle Unit (IVU)". IVU is equipped with GPS receiver that receives communication signals from GPS satellites and calculates its position. This data is transmitted

to TS through GSM/GPRS based modem. The data can be transmitted using direct IP/TCP connection with TS through GPRS or by using SMS on GSM network. TS additionally has a GSM/GPRS based modem that receives vehicle's location data via GSM network and stores this information in a database. This information is available to licensed users of the system via respective websites.

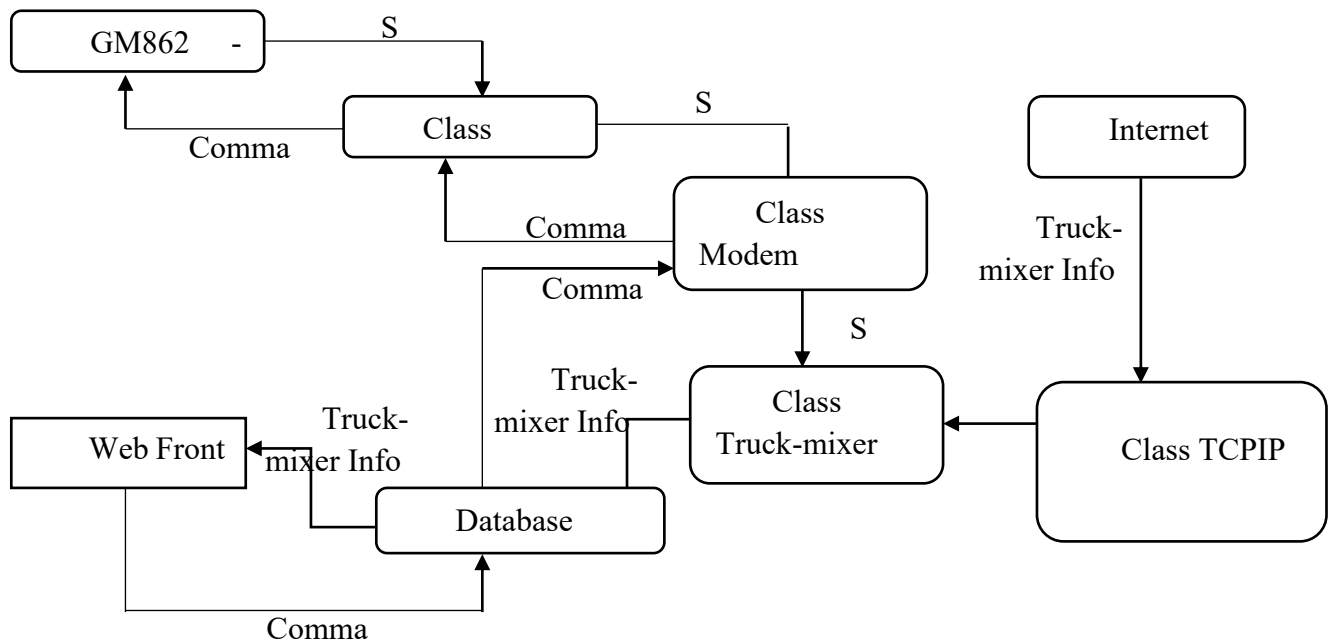


Fig. 5 Data flow of communication software

### System Design

Overall system is partitioned off into two major design units: Tracking Server/Monitoring Station (TS) and In-Vehicle-Unit (IVU)

### Design of Tracking Server (TS)

TS maintains the information received from all of the IVUs installed in IVU is designed using OEM module TelitGM862-GPS is the same GSM/GPRS modem that is used in IVU. It is employed on the server side to exchange information with IVUs through SMS. Vehicle's data sent by IVU through SMS is received by this specially designed modem on TS. TS can additionally send commands for IVUs using this modem. The GM862-GPS interface board is linked to the serial (COM) port on server. The server can transmit with the modem using AT commands. To broadcast and obtain data using this modem communication software is needed. The communication software system provides communication interface to the GM862- GPS specially designed modem connected to the computer's interface. It is responsible for communicating and controlling the operations of GM862-GPS. Fig. 5 shows the data flow of the communication software. Main program listens for SMS messages. It manages all of the

communication with IVUs using SMS. It produces a separate thread for listening to TCP/IP connections, which receives incoming connections from IVUs and creates a separate thread of thought for each incoming connection. It permits any number of IVUs to connect the remote TS. The database is designed to store all of the relevant information on vehicles, such as In-Vehicle units and users of the system. To expose this information to the end-users a front-end application/software is needed. The end-user is the user of the system who has installed the IVU in his/her vehicle. The administrator of the system, who is liable for all the activities happening within the system, additionally needs to access the current info. This is accomplished by producing a network interface for end-users and decision maker.

#### **4. Conclusions**

Based on the analysis carried out it has been observed that for “wireless sensors network” the power consumption is low resulting in longer battery life, but there are high chances of multiple path error due to reflection of signals due to physical obstructions. For “radio frequency identification device”, the tags are cheaper compared to sensor tags and network infrastructure is not required to that extent, but the power consumption is high compared to wireless sensors. The “global positioning system” accurately tracks the location in an outdoor environment but provides inaccurate data for close proximity and exhibits multipath error due to physical obstructions. Thus it has been recommended that the RMC delivery in the construction sites of urban area can be carried out through an improved approach in the form of integrated navigation system. Feasibility of automated event time collection and using GSM networks for wireless data communication under the practical application requirements was also explored. This research paper gives the formulation of the integrated navigation system to production scheduling and vehicle routing. Going through such systems may increase the number of fulfilling orders, improve plant and truck-mixer utilization rates and client satisfaction and, as a result, help to attain competitive advantage in the extremely demanding marketplace of RMC production.

As a scope for future research, there should be an attempt in increasing positioning accuracy of the system, especially in sites located in urban canyons. Possibilities of exploring more reliable data communication technologies, such as GPS based on information flow and also extending RMC monitoring from on-route to on-site, which could significantly improve the delivery operations of RMC plants and thus broaden the application value of the system in construction management.

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# Microtunnelling of Wastewater Collector System – Experiences from the City of Mostar

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## Abstract:

Water pollution is one of the most serious environmental pollutions and since 2014 the City of Mostar have been implementing a project on construction of a wastewater collector system with an estimated cost of approx. EUR 128,000,000. The microtunneling technology has been applied in Bosnia and Herzegovina for the first time. This paper highlights some occurred problems and experiences obtained during the construction. A bad design of the project documentation due to incomplete geotechnical testing and insufficient number of trial holes, a lack of a precise underground cadaster, pedestrians’ safety, traffic regime and on-site delivery of large-profile pipes have been identified as major causes of the problems. It is concluded that microtunnelling technology is a useful technology for tunnel construction in urban areas, however this technology requires a design documentation that is prepared in a clear, concise and detailed manner. Also, an experienced and fully committed team needs to be appointed to manage the construction.

*Keywords: construction, wastewater system, microtunneling, project experience;*

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## 1. Introduction

Development of settlements and increase of standard of population cause environmental pollution and one of the most severe forms of pollution is water pollution (Yixin, 2017). Water consumption has been increasing on a daily basis, resulting in an increase in wastewater quantities, but in many cases wastewater infrastructure isn’t among priorities of the settlements (Yi and Zhengxian, 2018).

There are different types of water pollution: physical, chemical, biological, radiological, etc. Given the place of origin, urban wastewater can be divided into: sanitary, industrial and stormwater. Industrial wastewaters differ depending on a type of industry or a technology process (Garbowski *et al.*, 2018).

Basically, industrial wastewater can be divided into two categories: biodegradable (compatible) and biologically non-degradable (incompatible) wastewater. Biodegradable wastewater can be mixed with urban wastewater and carried by a combined sewer. Food industry wastewater mostly belongs to this category as they contain food-generated waste. Biologically non-degradable water need to be preliminary treated before mixing with urban wastewater. Treatment is carried out to remove explosive, corrosive and flammable substances (to protect sewer pipes), to remove inhibitors that prevent operation of wastewater treatment

plants and to control toxic substances that prevent biodegradation (Mayer, 2004; Tedeschi, 1997; Štrkalj, 2014).

To decrease the water pollution a large number of municipalities in B&H have initiated activities on construction of a network and a central wastewater treatment plant, such as Bijeljina, Mostar, Sarajevo, Bihać, Živinice, Banja Luka, Tomislavgrad and others. Wastewater facilities have to be given the necessary financial support in order to force sustainable development of the areas. Also, a multi-objective approach should be used during the decision-making process (Chen et al., 2018; Flores-Alsina *et al.*, 2008; Xudong *et al.*, 2018). Experiences from past similar projects should be examined, too. Therefore, the aim of this paper is to present some experiences obtained during the construction of the waste water collector system in the city of Mostar.

## **2. Construction of a Wastewater Collector System in the City of Mostar**

During the war lasting from 1992 to 1995, the urban infrastructure of the City of Mostar was severely damaged. After the war's end, some donations were granted for reconstruction of the infrastructure, however, they were not sufficient to establish a functional sewage system. At that time the sewerage system in Mostar was outdated, damaged, and without any main city collectors for carrying wastewater outside the City center. The network was not completely built, i.e. it did not collect all sanitary and storm water. In most cases, it was a combined sewage system and all collected storm water and wastewater (both urban and industrial) ended in the Neretva River at about 30 different discharges. There was no wastewater treatment plant at that time. In addition to domestic wastewater, significant quantities of wastewater were also industry-generated. Quality of the Neretva River water and its tributary, the Radobolja River, has deteriorated due to the large number of sewer pipes discharging their contents directly into these watercourses.

Aimed at addressing the aforesaid issues and constructing a sewage system that will ensure development of the City of Mostar, while simultaneously reducing environmental pollution by wastewater, a study "Mostar Urban Environmental and Water Quality Plan" was prepared by MWH USA&Integra Mostar in 2004. This study investigated an area divided into 3 separate zones, namely the Central Valley Service Area, the South Valley Service Area and the North Valley Service Area.

The Ministry of Finance and Treasury of Bosnia and Herzegovina in 2008 signed a loan agreement with the European Investment Bank (EIB) for financing the project "Water and Sanitation in Bosnia and Herzegovina" - WATSAN BiH (MWH USA & Integra Mostar, 2004). The aim was to support improvement of current living conditions of the population, ensuring adequate hygiene conditions for water supply and wastewater treatment in compliance with the EU accession requirements and for harmonization with the EU legislation.

The WATSAN BiH project initially covered 20 municipalities in the Federation of Bosnia and Herzegovina. The total investment is estimated at approximately 121.3 million Euro, out of which 60 million Euro is provided from the EIB loan and the rest from own funding sources, i.e. city/municipal budgets and grants from other donors.

The city of Mostar has been involved in the WATSAN BiH project through implementation of development of the central zone sewerage system. The project has been focused on the primary collector network and only to a small extent to the secondary network and the connections, which means that some of the facilities of the system constructed under the WATSAN BiH project will not be sufficiently exploited over a longer period of time (this was one of the conclusions of the Project Implementation Team).

Development of the central zone sewerage system is Phase 1 of the project implementation. This phase includes construction of main city collectors along the Neretva River (Figure 1).

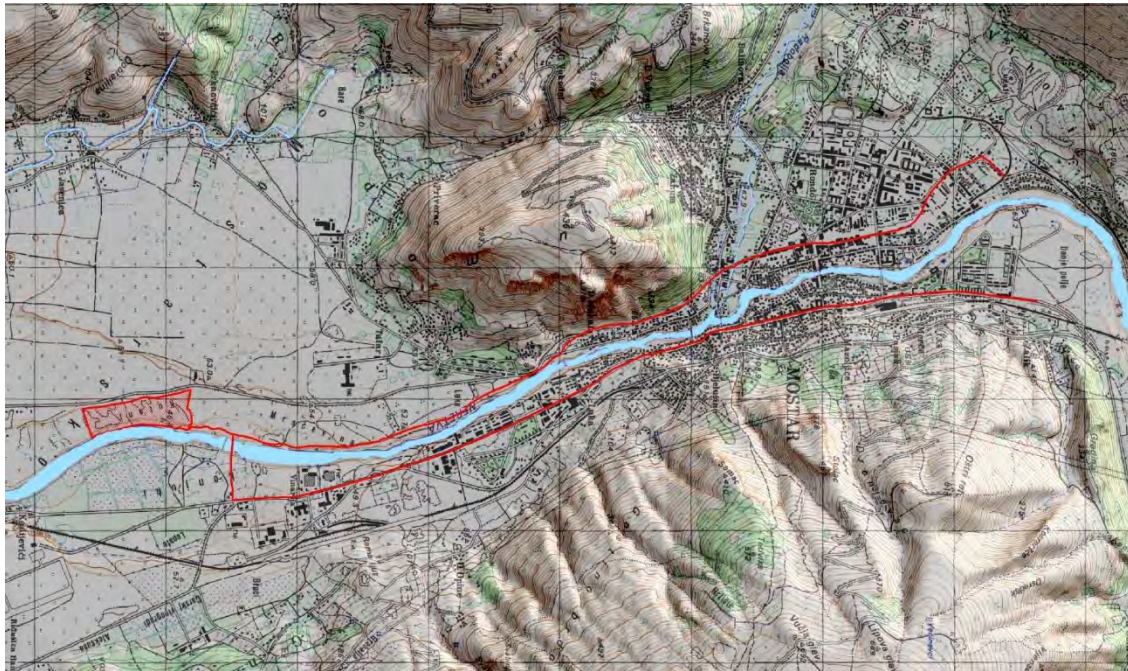


Figure 1. Main city collectors and the site of the wastewater treatment plant in Mostar (MWH USA & Integra Mostar, 2004)

During the period from 2012 to 2018 two major sewage collectors on the left and right banks of the Neretva River and a syphon crossing of the Neretva River for a connection of the left and right river bank collectors were under construction. At the same time, but not within the WATSAN BiH project, some activities on construction of a wastewater treatment plant with a capacity of 100,000 population equivalent were also carried out, and its construction was completed.

At the time of writing this paper both, final works on construction of the main left river bank collector and the siphon and activities on construction and connection of secondary collectors are still ongoing. The main collector of the right river bank was already connected, whilst the main collector of the left river bank is not operational yet and it is not connected to the wastewater treatment plant, which has been the main objective of the entire WATSAN BiH project. Thus, the Neretva River is still significantly polluted.

The technical features of the main river bank collectors of the central city valley are as follows:

- Left-river bank collector: sanitary, gravity, length approx. 7 km, diameter ranging from 300 to 800 mm.
- Right- river bank collector: mixed, gravity, length approx. 7 km, diameter ranging from 900 to 1,400 mm, four rain overflows.

The result of this project for the City of Mostar should be a constructed collection system that carries most wastewater from the central city valley to the wastewater treatment plant. First of all, Neretva River water will be much cleaner and the environment will be more preserved. Offensive odor citizens and tourists in residential and catering facilities located along the Neretva River have been exposed to for years will be eliminated. Pollution reduction achieved by this project will have positive impacts on the environment of the Republic of Croatia, as the Neretva River flows into the Adriatic Sea.

**It is expected that the number of people affected by direct contact with the waters from the river will be reduced.**

### **3. Construction of a Wastewater Collector System by Microtunneling**

The microtunneling method was applied for the first time in Bosnia and Herzegovina during the construction of the collectors in the city of Mostar. In the old part of the City, in Marshal Tito street, an underground tunnel was constructed on the section from the National Theatre to the Old Bridge instead of surface excavation in order to minimize disturbances of urban traffic, local population and a large number of tourists.

#### *3.1. General information about microtunneling*

Microtunneling is a modern and highly precise trenchless, remotely controlled, steerable, pipe jacking technique with the use of laser guided systems (Dietrich *et al.*, 1989). It has an articulated steering unit. It is primarily used for construction of pipelines with larger diameters and lengths. It can be used on any type of soil, in presence of groundwater. The laser-guided system guarantees great precision. It is most commonly used in city centers to avoid large traffic jams, also to avoid obstacles such as mountains, highways, railways, etc. Entrance and exit pits are located at the beginning and the end of a pipeline trench. The tunnel is solid and enables risk-free movements through the tunnel. The entire process is monitored and operated from a control room in a container located at the top of the entrance pit using a computer.

A cutter head equipped with tools selected according to soil the conditions is placed on the front of the machine. The alignment of the line is given and controlled by a guiding system. The guiding system is selected according to length, curves, etc., and is monitored and adjusted by the contractor from the control room (Dietrich *et al.* 1989; French Society for Trenchless Technology, 2010).

#### *3.2. Microtunneling in Marshal Tito Street in the City of Mostar*

Marshal Tito Street has a convex vertical curve and a cave (a tourist attraction) near the Old Bridge in the area where microtunneling was carried out. It is mostly located in the B category soil. The tunnel is located at a depth of 6-12 m and its diameter is 1500 mm. The



dynamics of construction of 6 m a day has been achieved. The length of the tunnel is 306 m. The route was chosen in such a way as to bypass the cave located near the Old Bridge, Figure 2.

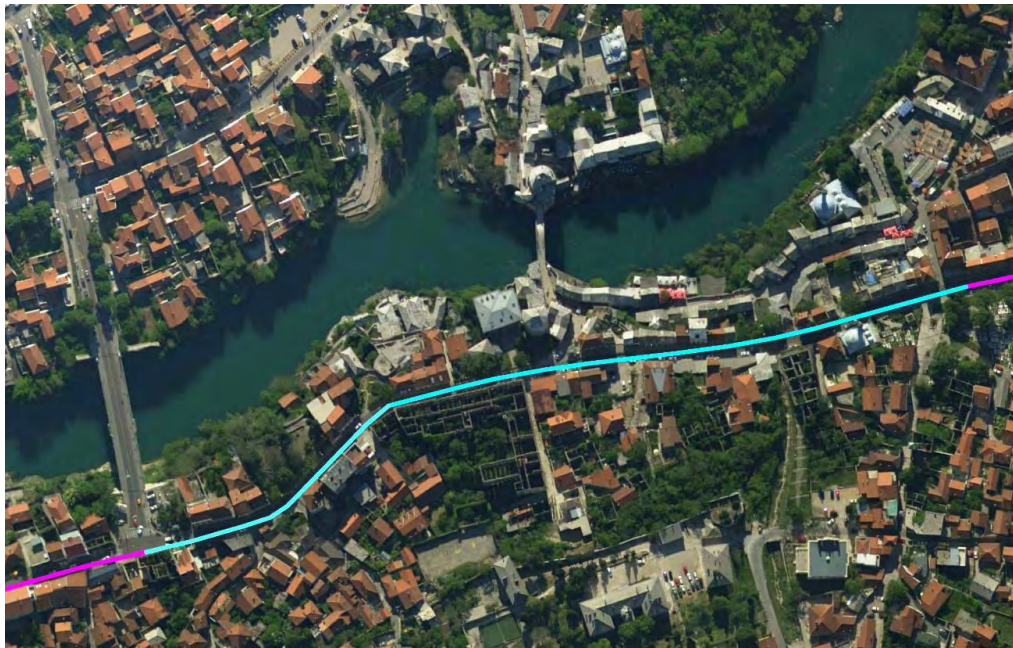


Figure 2. Tunnel near the Old Bridge, (Marshal Tito Street)

Work phases have included: construction of entrance and exit pits, assembly of equipment, drilling and laying of pipes, disassembly and removal of equipment, restoration of the terrain to its original condition. Figure 3 and Figure 4 show the entrance and exit pits of the microtunnel.



Figure 3. Entrance pit of the microtunnel



Figure 4. Exit pit of the microtunnel

It is necessary to provide clean water supply and removal of excavated material within the entrance pit. A connection of a water pipe and a tube for removal of excavated material is carried out. The drilling equipment is set up in the entrance pit using a crane. After setting up

the equipment, microtunneling begins. In order to successfully carry out pipe jacking operation, it is necessary to build a reaction wall on the opposite side of the microtunnel opening.

A laser is used to determine the precise position of the machine and for target guidance.

Special attention is paid to occupational safety. Operational personnel never come into contact with the excavation front and thus all hazards of underground operation have been eliminated. Drilling is performed under maximum safety conditions as the contractor controls all drilling parameters through a single control panel. The exact position of the plate itself is known at all times with help of a laser beam directed at the target point on the rotating plate. Periodic geodetic inspections and adjustments ensure high excavation precision.

Tunnel lining consists of prefabricated reinforced concrete pipes with watertight joints. The tunnel is lined by pushing and inserting cast-in-place reinforced concrete pipes so that the tunnel gets a high-quality finishing lining simultaneously with excavation. Concrete elements have built-in injection valves in a gap between the pipe and the surrounding ground for lubrication purpose. Joints are designed to absorb designed angular deviations and deviations that occur during insertion. Joints shall ensure water-tightness.

The excavated soil mixed with a concrete suspension is transported through a tunnel. This mixture called sludge is pumped back through the tunnel using hydraulics.

After drilling and visual inspection of the tunnel (to detect any irregularities, cracks or cavities) laying of pipes can start.

Microtunneling operators and construction manager monitor and report on drilling parameters. Also, it is necessary to visually monitor slumping of the street and buildings on the microtunnel route and carry out geodetic survey of slumping of the rappers installed on the existing structures based on the zero-state study of the structures. Furthermore, it is necessary to monitor and report on bentonite level, carry out a dynamic plate bearing test and compile a report, conduct a waterproof test, etc.

#### **4. Problems occurred during the construction**

The construction of collectors in the City of Mostar has started in 2014. This has been certainly one of the most significant projects for the City implemented so far, as the only sewage recipient used to be the Neretva River.

During the construction numerous problems were encountered by project stakeholders, particularly by contractors, as well as by the citizens and tourists (Figure 5).



Figure 5. Construction site at the main City Square

Collectors were laid at several locations simultaneously, thus blocking of streets and lack of traffic lights seriously influenced the urban traffic regime, as the construction site is located in the center of the city frequented by a large number of vehicles and pedestrians (including tourists) Figure 5 and Figure 6. Only two out of total four lanes were in use in both directions, causing kilometers-long traffic jams and redirection of drivers to side roads. Furthermore, some problems also occurred during on-site delivery of large-profile pipes. During the work execution the City authorities were constantly issuing press statements asking for patience and understanding and especially kindness towards tourists.

The existing underground installations, such as water supply, electricity, etc., significantly slowed down works execution. A lack of a precise cadaster of underground installations caused significant difficulties to the contractor resulting in both planned and unplanned infrastructure disconnections at the construction site during works executions. Entire settlements were occasionally left without water and electricity supply, telephone, television and internet connections, which influenced living comfort of the citizens.

A serious problem was caused by the existing obsolete water pipes at a depth of 1.5 m (the depth of excavation for collector is approx. 6 m). During excavation works these pipes used to crack at connections. Because of this, it was necessary to relocate the existing water pipe several times, or to make temporary bypass in order to provide water supply during works execution. New water pipes were placed only after laying the sewage pipes, but acquisition and delivery periods of large profile pipes needed a special attention.



Figure 6. Construction of a stormwater outlet below Tito's Bridge

The errors in the design documentation related to geotechnical surveys caused some major problems for the contractors, due to a significant deficiency in the project design documentation that had occurred because of incomplete geotechnical surveys and insufficient number of trial holes. Namely, 12 sites were surveyed within the scope of previous geotechnical surveys of the site. The following was established with the geotechnical documentation:

- Conglomerate prevailing in the geological composition was found at all sites;
- The conglomerate found is present in various forms;
- A small part of fine particles was detected near the siphon location;
- Geo-mechanical tests showed that the underground soil composition is suitable for works execution;
- Excavation without mining is feasible.

The assumed material features were not even close to the actual features at several sections. The error was especially evident in the busiest city street, where it had been assumed that only 20% of the terrain had characteristics of B category, and approx. 80% C category. However, the situation on the ground was just the opposite. Thus, the excavation of this terrain was more money and time consuming than originally envisaged. Works on that route should have been supposedly completed by the end of the summer, however they were prolonged throughout the winter. Due to this, the main donor questioned the whole project and implied a possibility of claiming back the funds invested. The City authorities were constantly in sessions, the Contractor worked in two shifts. As the digging depth was unpredictably 6-8 m in rocky ground, mechanical defects were occurring. The aggravating circumstances were the large population density of this part of the route, high traffic circulation, and presence of numerous pedestrians, Figure 7.



Figure 7. Works on the main City street (the National Revolution Boulevard)

## 5. Conclusion

The microtunneling technology used for wastewater collectors' system construction in the City of Mostar is considered a major undertaking since it has been applied in Bosnia and Herzegovina for the first time. However, due to the complexity of the project and its long duration, numerous various problems were occurring during the construction. Hence, based on the experiences from the construction, the general conclusion is that the microtunneling technology is a complex, full attention-requiring, but useful technology for tunnel construction in urban areas.

In order to reach any set project goals, this technology requires a concise and precisely prepared design documentation based on conscientious and thorough geotechnical investigations. Also, a detailed underground cadaster must be used as a baseline for organization and construction technology preparation for such a project. Furthermore, all aspects of the construction, such as traffic, pedestrians, organization and technology of construction, schedule, health and safety of construction works, workers selection, etc., need to be elaborated with particular attention, in detail and on time.

It can be also noted that the microtunneling technology needs to be managed by an experienced project management team that is fully dedicated to a successful project implementation.

Although the experiences regarding project implementation and construction explained in this paper are the country-specific, we hope they are useful for solving some problems that can occur in similar projects, not only in BiH, but in other countries, too.

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# Reconstruction of Traffic Surfaces Pavement Structure of Electrical Energy Facilities

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## Abstract:

Reconstruction of internal traffic area (road) within power transmission and distribution substation or other electrical power plant is complex and demanding investment which requires cooperation and synchronism of participants coming from various engineering background. It is carried out mostly alike as ordinary road but taking in account additional regulations due to safe operation and use of equipment in hazardous areas close to electrical installations and apparatus.

Safely engineered and well-built road connecting public road and internal road of power substation has a key role in aspects of: safe and fast access of heavy machinery and trucks close to electrical equipment for normal service or during the intervention (failure, damage, fire, oil spillage), water drainage, reduction of maintenance costs.

During the reconstruction of asphalt pavement surfaces on power plants, it is necessary to consider that parts of substation are supplying electricity. Before any work is started, preliminary precaution measures are set. These consist of: detecting area close to high voltage and detection of borders of safe working area (surface but also in height).

Prior to reconstruction it is necessary to carry out preparatory work on parts of distribution network and power substation such as: detecting existing cables and facilities, creating an earthing mesh, laying new power cables, laying signaling and communication cables, building oil-drainage system and firm surface.

When substation is switching network state or is in faulty condition – no work is allowed until normal operating condition is established which may affect the time limits of project.

Throughout the reconstruction it is important to coordinate work on electrical installations and civil (construction) works and to try to achieve maximum quality. Another key issue is communication among engineers from a various discipline and trying to understand and develop best practice for future projects.

**Keywords:** *substation; traffic surfaces; pavement structure; energy facilities*

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## 1. Introduction

The subject of this paper is the reconstruction of the traffic areas of TS 35/10 (20) kV within medium voltage electrical power installations. Reconstruction of SS (power substation) 35/10(20) kV Tkalec is presented in detail, with description of: situation prior to reconstruction, requirements and general technical design and with description of main project phases and specific works.

In this paper emphasis is placed on the construction part of the reconstruction, which includes preparation of documentation and realization of capital investment [Tunjić, 2017].

Key documents for defining the scope and need in preparation of capital investment need are development studies and development plans. The basis for the development of multi-year development plans (ten year development plan, with detailed list of activities for first 3 years) is the study of the long-term development of the distribution network Elektra Bjelovar shown in Figure 1.

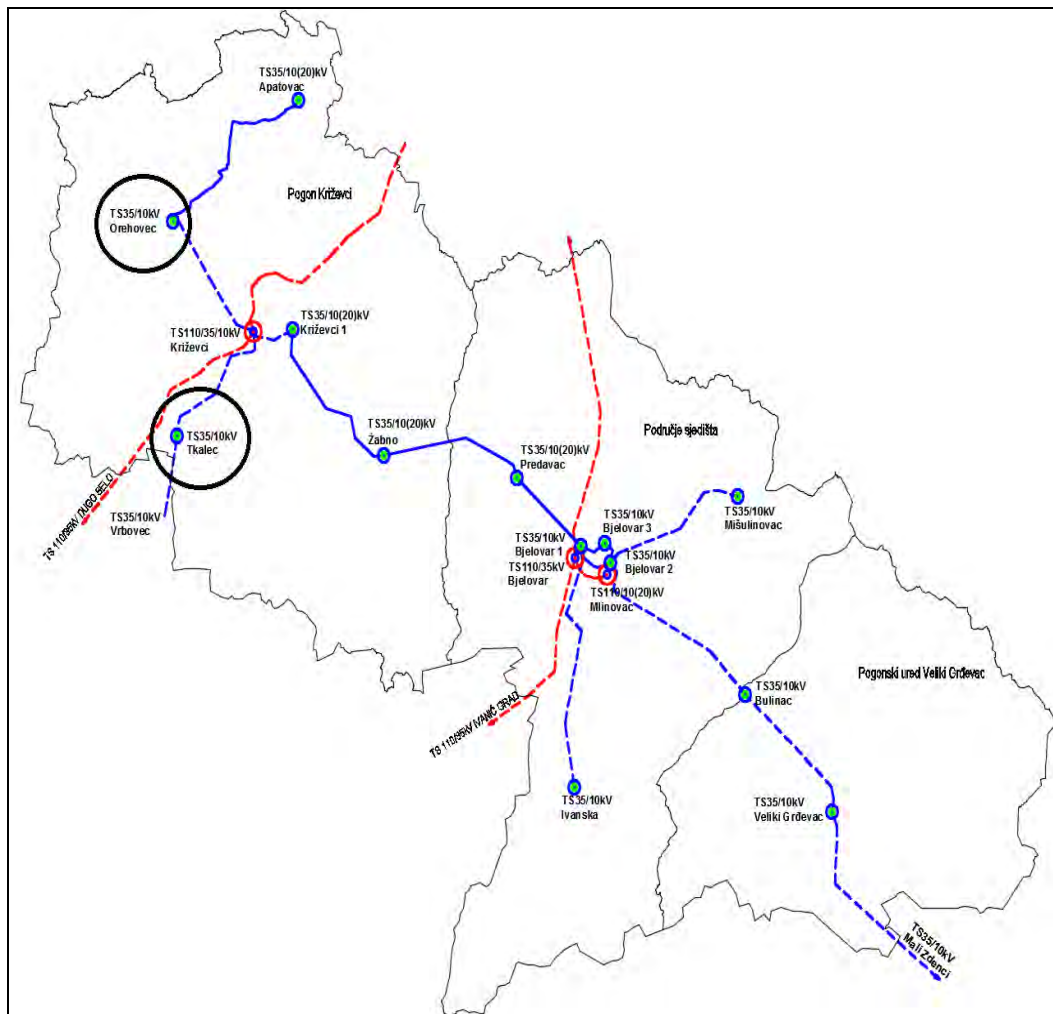


Figure 1. Scheme of the Elektra Bjelovar network [Tunjić, 2017]

When carrying out construction works on the reconstruction of this capital building, it was important to take into account the quality of work, the coordination of electrical and building works, compliance with legal regulations (occupational safety, fire protection) as well as



construction phases. The purpose of this reconstruction was to increase the reliability of distribution, the safety of workers working on plant management, the reduction of maintenance costs and the reduction of losses in the distribution network, which means creating the prerequisites for a reliable supply of electricity.

Presented SS 35/10(20) kV Tkalec was built in 1978. Given that a certain period of time has passed since the substation has been built (estimated lifespan of building was cca 50 years), the reconstruction of the facility has to be carried out to ensure the safety of the facility itself, the safety of workers working on plant management, maintenance costs reduction and loss reduction in the distribution network.

## **2. Reconstruction of TS 35/10 (20) kV Tkalec power substation**

Reconstruction of Tkalec power substation TS 35/10 (20) kV [Mihal, 2014] was performed on previously defined building area (appropriately registered in local land registry). The exterior of SS (substation) with internal road, building and underground installations is located inside a fence on a paved part of a building area a plot. The replacement of the 35 and 10 kV plants of the existing TS 35/10 kV was done using new 35 and 20 kV rated voltage enclosed design switchgear for additional safety and low maintenance. The switchgear was in poor condition, also close to the end of its lifespan, without the possibility of purchasing spare parts (equipment of older design that was no longer manufactured). Because of this, it was no longer possible to guarantee a continuous and secure supply of electricity to customers connected to the grid from the substation in question. The drainage system of rainwater and oily water did not work, and the need for reconstruction was imposed. There is no public water supply and sewerage system in this area. The internal road is asphalt concrete sloping pavement in poor condition as well as a protective fence, along with the associated entrance entrances, ie the compound to the public surface. Figure 2 shows the existing state of the TS 35/10 (20) kV Tkalec object, and Figure 3 shows the situation of the existing condition.



Figure 2. Existing condition of TS 35/10(20) kV Tkalec

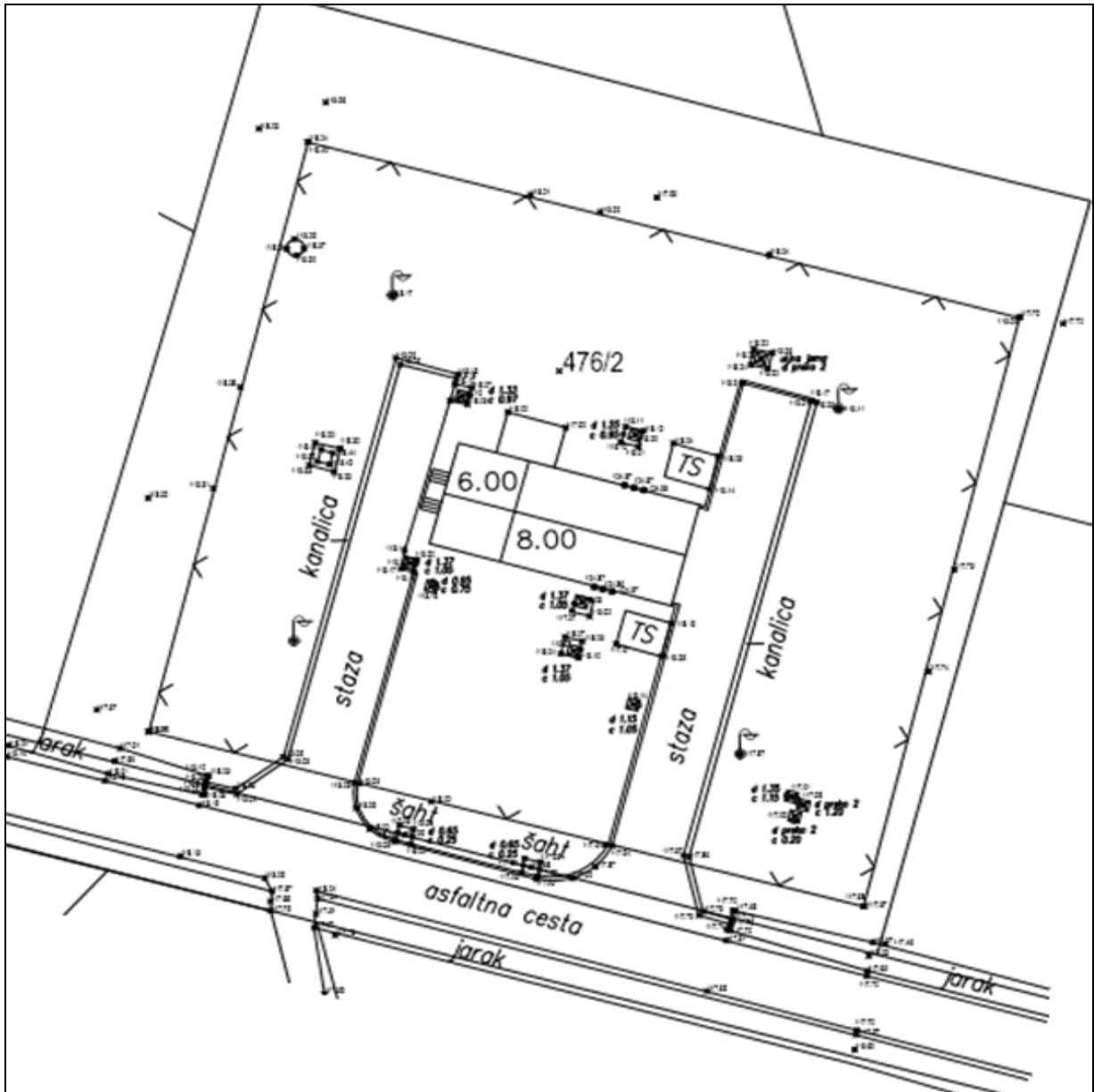


Figure 3. Situation of the existinf condition of TS 35/10(20) kV Tkalec [Mihal, 2014]

### 3. Project technical design

Main technical design documentation defined the elements of managing the internal traffic and connecting the station to the public road. Basis for the main technical design are documents with technical requirements prepared by engineers of local HEP ODS Elektra Bjelovar. Complete main technical design (civil engineering and electrical parts) were used as the basis for detailed design technical documentation and to obtain all necessary permits.

Table 1 shows some items per substation, such as parcel surfaces, road widths, and road lengths.

Table 1. Dimension view of the road and the particle surface

Dimension of the road and the particle surface	Power substation Tkalec
Particle size	6870 m <sup>2</sup>
Road width	5,5 m
The length of the road	81,8 m

The power substation [Piteša, 2016] is located in the middle of the lot, while on its north and south side there is one power transformer on the reinforced concrete foundation. Trees and pedestrian entrances to the parcel were derived from the south, with the public traffic area located on cadastral lot 1009/1 land registry district Tkalec, in the settlement of Tkalec (recorded as a road). The existing public area and the connection are asphalted as well as the internal traffic area. Lots are not asphalted or in accordance with the design of the environment are designed differently, with a final covering of humus and grass planting. A concrete pavement was erected around the transformer station building, elevated for the height of the curb from the asphalted surface, and from the green surface separated by a concrete precast pedestrian margin of 8/20 cm. Drainage of rainwater from the plateau of the transformer station is performed by the gravitational transverse and longitudinal inclination of the traffic surface and the concrete pavement by the green belt, or by the prefabricated drainage duct with the drainage. The rainwater from the roof of the building is leaps and bound to the ground. The wastewater depleted by the transformer is connected to an oil well, after which a siphoning of the separator is ensured. Behind the sewage separator after the treatment, an overhead station was built (water can't be drained gravitationally). Since the transformer station does not have a permanently staffed staff, the building does not need a sanitary node. Situation of the projected state TS 35/10 (20) is shown in Figure 4.

The treads come as sliding and pedestrian as winged. All entrances are grounded with metal parts. On the outside, concrete grooves were constructed to prevent rainfall from the public traffic area on the parcel. The width of existing internal roads is 5,5 m in width. The southern route is seen only for the traffic of the vehicle, while the northern road is also intended for entry of a workforce to be maintained in the transformer building. The roads are designed for heavy equipment transport (power transformers) and are designed to receive the highest cargo and the possibility of manipulating the same. Around the foundations of the transformer, waterproof bulkheads were introduced to prevent any oil flow from the energy transformers in the field. The waterproof tubs are drained and the drainage system is connected to a factory-made oil separator.

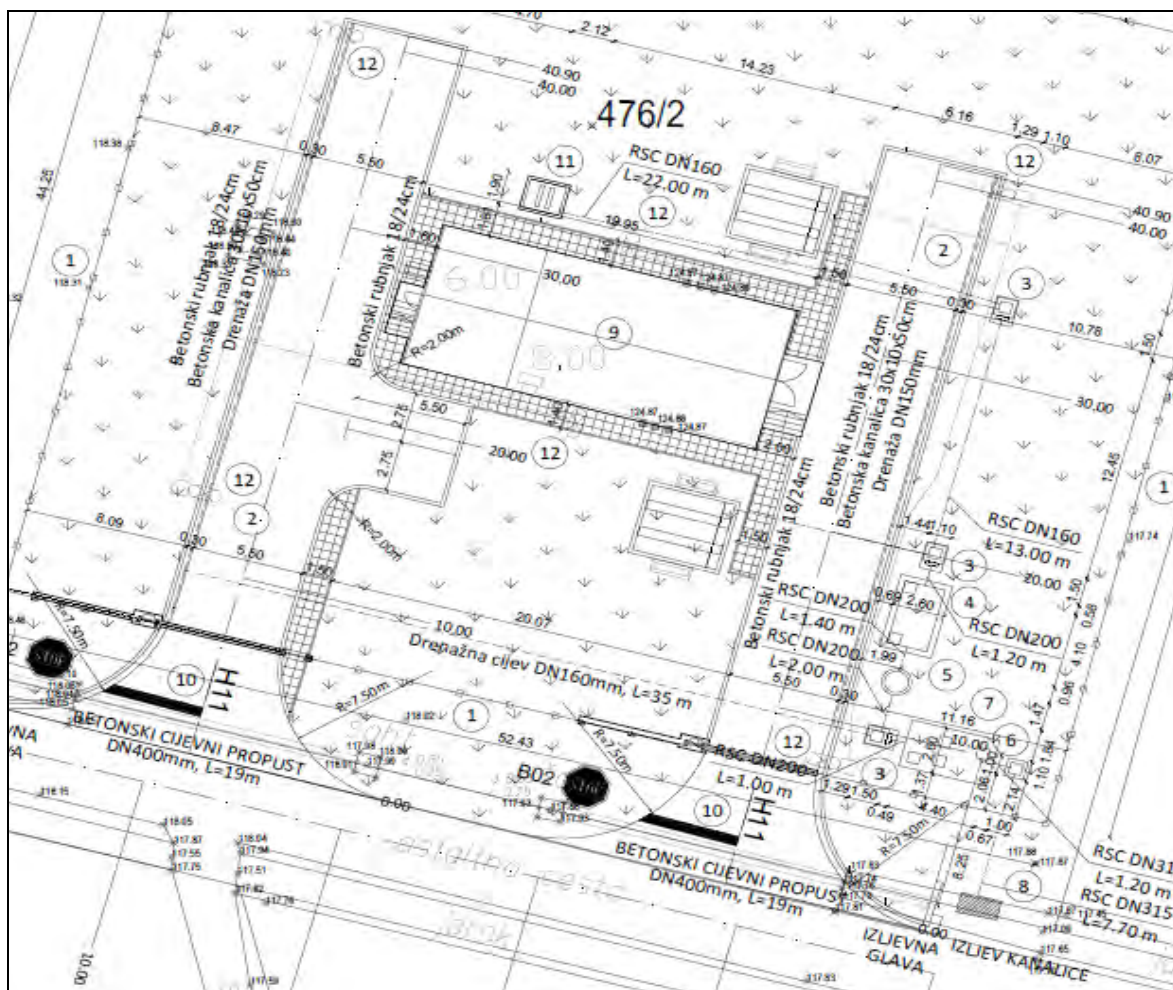


Figure 4. New design of TS 35/10 (20) kV Tkaliec [Piteša, 2016]

#### 4. Performance of reconstruction of traffic surfaces

Regarding reconstruction work, they are usually reduced to working ground, access roads, drainage systems, oily sewers, oil pits, separator installations, precision stations construction (depending on the terrain configuration) and the connection to the existing sewage system or as a in the case in question in the drainage channel or into the submersible well. During the preparation of the construction, and through the construction itself, good experiences of previous or similar reconstructions of transformer stations are applied. Below, this practice is described by reconstructing the substation throughout all stages of the work. Table 2 shows the quantities of individual works.

Table 2. Presentation of completed works

Quantities of finished works and layers	Power substation Tkaliec
Quantities of earthen works	785 m <sup>2</sup>
Amounts of the derived load-bearing layer of stone material	350 m <sup>3</sup>
Surface of the asphalt surfacing layer	535 m <sup>2</sup>

#### 4.1. Preparatory work

The preparation of the reconstruction of the substation is a very important, demanding and responsible work due to the length of the works, the length of construction, the participation of a large number of executors and other specific features typical of the reconstruction of the substation. Preparatory work on the construction site mainly refers to the registration and construction of construction sites. Prior to the beginning of the construction work, all the activities that are required to be reconstructed in accordance with applicable laws and regulations are well planned, within the agreed deadline and with respect to the contracted economic and financial conditions. In that sense, a project of the construction organization (PCO) has been previously drafted.

Preparation of the construction - during the reconstruction of the substation, continuous control of the organization of the construction site, technical equipment and mechanization was carried out, all in accordance with the requirements of the project and the mechanization. Figure 5 shows the preparation of the construction site TS 35/10 (20) kV Tkalec.



Figure 5. Preparation of construction site TS 35/10 (20) kV Tkalec with a construction board

Field terrain - was carried out with the application of hygienic-technical protective measures and safety measures at work, without causing damage to surrounding facilities, property along the route and property at all. The activities carried out to clean the terrain were: clearing the bushes and trunks, demolishing three trees, which was especially taken care of by not demolishing trees not destined for demolition by demolishing the trees. Also, demolition of the foundation from the transformer and the upper part of the concrete blocks of the existing well generated significant amounts of construction waste material (concrete waste) which was necessary to be adequately disposed of. The terrain is completely cleaned off from waste and preconditions are created for the smooth running of construction works.

Geodetic works - during the reconstruction of the substation they included:

- tracing routes and all facilities on the route and across the road,
- all measurements related to the transfer of project data on the ground and vice versa,

- maintaining school markings on the field throughout the period from the beginning of the works to submit all papers to the investor and
- making a footage of the performed condition.

Geodetic control determines the height and position of the starting state or the state of the performed part of the construction.

#### *4.2. Earth works*

After all the preparatory activities were completed, excavation work involving the removal of the humus layer  $d = 30$  cm from the part of the area where the project envisages the internal route was started. During the removal of the humus layer, cleaning of the excavation material was performed for the purpose of installation in the final layer of the green surface.

For the purpose of building the groundwork of the substation and the sealed sewers, the drainage system has been excavated in the material "C" category (all materials that are not required to be mined but can be digested directly, using suitable machines - bulldozer, excavator, or skidder).

The excavations were carried out for the purpose of creating a working ground, ie laying the ground bar and creating an oil well needed to receive the transformer oil, installing oil and grease separators, a precursor station and a revision shaft and drainage system of the drainage system itself.

The excavated material dumped on the site as it could be used to cover the canals and around the construction pit, while part of the material that was sensitive to atmospheric impacts and could not, as such, be used in further construction work, loaded into trucks and drove to the nearby dump.

Creating placards - placenta is made of mixed material (earth-stone) thickness up to max. 50 cm (excavation material "C" category). The finishing layer was made with the characteristics  $M_s = 30$  MN/m<sup>2</sup>,  $S_z = 100\%$ , as the road was carried out in mixed material. The stem was made in a transverse drop of 4.0%. On the ground beneath the traffic surfaces a non-woven geotextile 200 g / m<sup>2</sup> was installed. The overlap of the geotextile was performed in the direction of bending in the length of 50 cm [Mintas, 2001].

#### *4.3. Pavement construction – project condition*

As part of the reconstruction project of the TS 35/10 (20) kV [Piteša, 2016] substation, reconstruction of the existing traffic surfaces and the connection of these traffic surfaces to the public road as well as the design of the environment on the remaining space within the fence were performed. The dimensioning of the pavement construction [Babić, 1997] was carried out by empirical method according to the valid HRN U.C4.012 standard for the road construction type 1 - pavement construction consisting of asphalt layers and a layer of mechanically coated grainy stone material. In order to access the newly designed roads, the existing internal roads have been removed. New traffic surfaces are made as flexible asphalt concrete pavements.

The connection is made of the type APPROVED according to the rules on design conditions and construction of connections and access to the public road and with the consent of the county roads. Radiation radii radius on the public transport surface was  $R = 7,5$  m and the traffic area inside the trunk as an asphalt pavement. Two parking spaces of  $5,50 \times 2,75$  m have been built as part of the internal road. All works are carried out according to occupational safety regulations, as the object around which this road was constructed was a potential hazard for the workers (immediate vicinity of the power transformer).

Horizontal and vertical geometry of the internal roadway is solved through 2 axes.

The internal road with public transport access is made in the following section:

- traffic lane  $2 \times 2,75$  m,
- precast concrete channel  $30 \times 10 \times 50$  cm,
- concrete curbs  $18/24$  cm,
- pedestrian concrete pavement near the TS building,
- the green belt inside the fence.

The inclination of the inner road pavement is carried out at a slope of 2.5% throughout the length of the road, and the drainage of rainwater from the asphalt surfaces to the green surface along the transverse secures and the longitudinal slope of the joints. Sleeping is settled with two parking spaces.

In addition to the transverse profiles, the internal road of the TS 35/20 (10) kV substation is solved through two longitudinal axes:

Longitudinal road section axis-1, length  $L = 40,90$  m

- in the chainage 0+000,00 connection to the public traffic area (train and pedestrian entrance),
- the longitudinal slope of the road is max 0,25%
- width  $W = 5,50$  m + pedestrian walkway to the right,
- the ground plan is in the direction.

Longitudinal road section axis-2, length  $L = 40,90$  m

- in the chainage 0+000.00 connection to the public traffic area (train and pedestrian entrance),
- the longitudinal slope of the road is max 0,86%
- $W = 5,50$  m,
- the ground plan is in the direction.

The Tkalec power substation is located on a flat ground, so when the asphalt layer is applied, the maximum longitudinal inclination of the internal roads is retained due to the drainage of surface water. The cross-sectional profiles of the internal roadway shown in Figure 6.

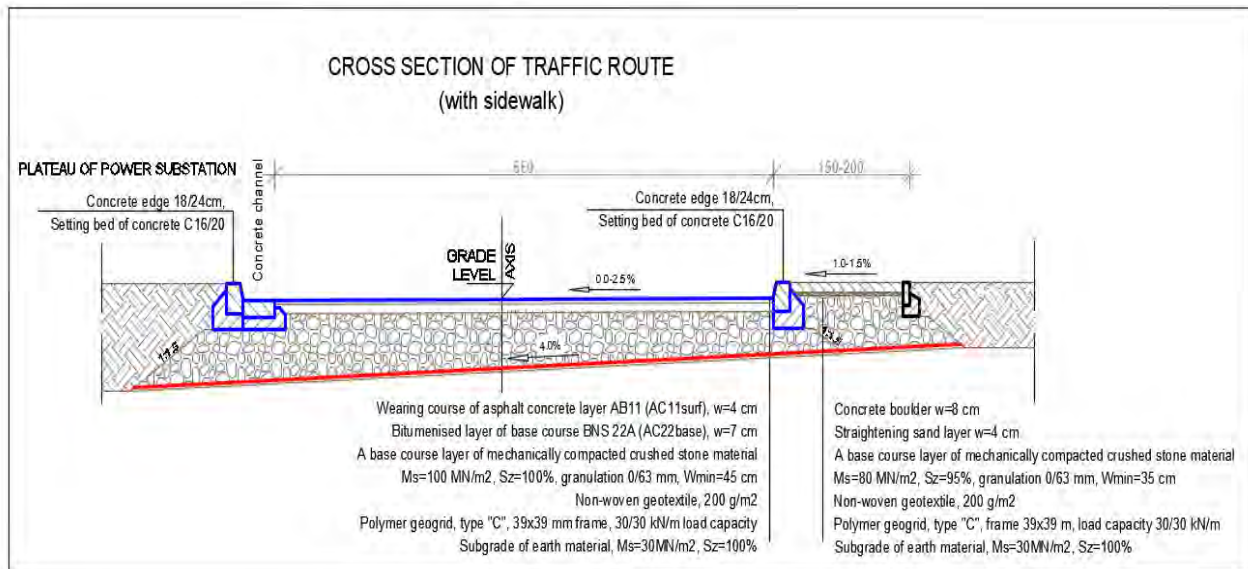


Figure 6. Cross section of traffic route and sidewalk [Piteša, 2016]

#### 4.4. Performance of lower pavement constructions

A 200 g/m<sup>2</sup> geotextile layer was installed on the plain of a mixed material for the separation of the placenta from the mechanically stabilized bearing layer of the crushed stone material Ms=30 MN/m<sup>2</sup>. The mechanically stabilized supporting layer of crushed stone material is made of unbound grained stone materials which stabilize by mechanical compaction Ms=100 MN/m<sup>2</sup>. For the separation of the road construction from the green belt, concrete edges have been made, and on the lower part of the concrete channel road. The edges are made of pre-cast concrete elements of 18/24 cm, placed in a concrete layer C16/20. When installing, it is ensured that no rubbish or cracks have been installed (Figure 7).





Figure 7. Curb installation along the road

For collecting surface water at the lowest point of the inner road, a precast concrete channel of 30x50x10 cm (Figure 8) is installed, placed on the edge of the concrete slab C16/20, thickness  $d=10$  cm.



Figure 8. Making concrete channels for the drainage of the road construction

Collected water from the traffic surfaces across the canal is drained and discharged at the inlet and outlet head of the drainage to the open drainage drainage channel, located along the public traffic surface.

On the prepared road bordered by curbs, a load-bearing layer of grainy stone material is performed. It was carried out by the conveying of grainy stone material and by spreading through the graders, excavators, and by compacting and grafting of grainy stone material by means of the razor and finishing.

When installing the material, it is ensured that there is no grain material segregation. Separation of materials appeared in local places and these sites were replaced by homogeneous material. Before the assembly itself and during assembly, the humidity of the material was

adjusted so that the humidity was about optimal moisture. The compaction started after finishing the planning and profiling shown in Figure 9.



Figure 9. View planning and and profiling of lower layer of the road construction

The compaction was carried out with vibration machines: vibrators, compactors and vibrators. The plastering was carried out carefully after spreading the material over the entire surface of the layer. Rollers and / or charging devices performed compression by moving at a constant speed of 2,5 km/h to 4 km/h. Particular attention is paid to good coat thickness. The layer surface was compacted in a way that it was a well-closed, uniform-mosaic look. In Figure 10 is shown placement arrangement of subbase.



Figure 10. Show placement arrangement of subbase

All sites that were not available for compaction machines (hiking trails, local places around the huts and places near the edges and canals) were made with a vibrator according to project requirements. Such places as well as work modes are approved by the supervising engineer at the proposal of the contractor.

## 5. Install asphalt mixtures

In order to achieve mutual bonding of the substrate and the applied asphalt layer, the substrate must first be sprinkled with bitumen emulsion.

Application of bitumen emulsion - the amount of bitumen emulsion for spraying the substrate depends on the level of roughness of the substrate, the type and type of bitumen emulsion, and the type and type of asphalt layer being carried out and applied in an amount that ensures the prescribed bonding of the layers. When spraying the substrate, the bituminous emulsion may be heated up to 60°C for unmodified or 70°C for modified emulsion [Sršen, 2001]. When an asphalt layer incorporates bituminous mixtures based on a modified bitumen polymer, the substrate must then be coated with a polymer modified bitumen emulsion. In the same application of bitumen emulsion on the reconstruction of the traffic surfaces of the substation, an unmodified bituminous emulsion was applied which was applied by means of a manual sprayer (small surface of the pavement).

Spraying the substrate with bitumen emulsion at an air temperature or substrate of less than + 5°C is not allowed. The installation of bituminous mixtures on the splayed substrate can only be started after the "breaking" emulsion phase has been completed. Surfaces that have been sprayed with bitumen emulsion have not been used for traffic, but only for setting the finisher to the initial position for the asphalt coating.

Performance of the supporting layer of asphalt - the predetermined load-bearing layer of the roadway construction of the internal substations of the substation is the supporting layer BNS22, d=7 cm (AC 22 base). It is a load-bearing layer in a pavement made of a mixture of stone flour, stone material and bitumen as a binder, manufactured and built-in by a hot process. Bitumen used for road construction bitumen BIT 50/70. Designed for easy traffic load. The installation was carried out by finisher and roller coil. The compaction was carried out using roller sets (combined roller and roller with sheaths), various characteristics and appearance. In order to make the rolling process as efficient as possible, it is necessary to form a set of rollers to achieve the optimal compactness of the asphalt layer. Prior to the execution of the supporting layer of asphalt the supervising engineer gives approval for the roller set provided by the contractor. After the performance of the bearing layer, a bitumen interlayer was used for interlaying the asphalt layers (a thin layer of bitumen obtained from bituminous emulsions or hot bitumen by spraying). It is made in the framework of the preparation of the substrate for the performance of asphalt layers of the pavement construction, in this case as a preparation for the asphalt layer.

Creating a Foaming Layer - The anticipated foam layer of the roadway construction of the internal roadways is the abrasive layer of asphalt concrete AB11, d=4 cm (AC11 surf). The floating layer AC 11 is an asphalt layer made of a mixture of stone flour, stone material and bitumen as a binder, wherein the granulometric composition of the rock composition is composed of the principle of the most complex stone material, the standard boundary area of the granulometric composition of the stone composition of the carbonate composition. The asphalt mixture is normally installed in a machine, but on construction sites where this is not possible, it can be handled with the approval of the supervising engineer, provided that the

prescribed quality of the asphalt layer [Sršen, 2001] is achieved. The installation of the foam layer itself is done with the finisher and rolling rolls. The compaction was carried out by means of a roller cushion set. Given that there were flat planes on the inside, there was no need for manual work.

## 6. Conclusions

Reconstruction of capital investment is a continuous process through which existing assets are reconstructed in terms of essential building requirements and ensuring the durability and safety of the facility and equipment. With the completion of the reconstruction process, HEP-ODS benefits from:

- reliability of electricity distribution,
- health safety for workers who work on plant management,
- reducing maintenance costs,
- reducing losses in the distribution network.

Capital investments, including the reconstruction of the traffic area described in this paper, are very complex and demanding investments that are planned over several years time and in significant financial amounts and require the reconciliation of the preparation phase and the stage of realization. In order to achieve the greatest efficiency in the implementation phase, all key planning documents with the documents from the preparation phase should be aligned. For the reconstruction of the traffic surfaces discussed in this paper it was crucial that the preparation phases were well done and that the project documentation was well prepared in the sense of a well-designed project task (main / execution project) and all the necessary permissions were made in time. The starting point for the start of reconstruction is the provision of financial resources in the Investment Plan required for the reconstruction of capital investments. A very important factor was the selection of a quality and reliable contractor who was able to perform all contracted works in terms of quality and deadlines of execution. It is important to note that the substation has been in operation for a long time, ie in no stage of the preparation and construction of the substation there was no interruption of the supply of electricity to the final customers. For this reason, it is of utmost importance to maintain regular communications and co-ordination meetings of all the participants in the construction phase (investors, contractors, supervisors) with a view to more efficient performance of the set goals within the given deadlines.

Problems in the construction process such as insufficient mechanization during the execution, the number of people on the site and the like are timely observed and eliminated without backlogs and consequences on the quality of the works and the financial construction.

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# **Sustainability in the Built Environment**

# Infrastructure Projects' Impact on Sustainable Development— Case Study of a Water-Utility Company

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## Abstract

Achievement of the United Nations' 2030 Global Goals for Sustainability (United Nations, 2015) is of paramount importance. However, for engineers and project managers to take meaningful action, they need to be provided with the practical tools, processes and leadership to turn grand rhetoric into viable engineering solutions. Linking infrastructure project sustainability performance to Sustainable Development Goals (SDG) targets is problematic. This paper builds on the previous development of an innovative Infrastructure Project Transformation Process Model, called the 'Infrastructure SDG Impact-Value Chain'(IVC) (Mansell et al., 2019b) to link tactical-level project delivery with global-level strategic SDG impacts. It uses a case study of a water utility company to demonstrate how the IVC process model can integrate the 'Triple Bottom Line' to ensure balanced definition of success across economic, environmental and social thematic areas. The results led to a proposed methodology for project leaders to align stakeholders on a common definition of project success during the design phase. It includes selection of longer-term outcomes and strategic SDG impacts – which it is suggested are improved definitions of project success. The practical application is significant since, with linkage of tactical delivery to strategic SDG impacts, improved investments decisions will be made, and systemic level lessons can be applied to increase the likelihood of success in achieving the SDG 2030 targets.

*Keywords: UN SDG; sustainable development; outcomes-impact; infrastructure projects; project success*

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## 1. Introduction

The construction industry has a major role in achieving a measurable impact against the SDG 2030 targets. The estimated USD \$94 trillion (Global Infrastructure Hub, 2018) of investment in infrastructure projects that is required globally by 2040, represents a massive opportunity to stimulate economic prosperity, reduce poverty and raise standards in health, education and gender equality. However, the linking of infrastructure project success to SDG targets is problematic as a recent Institution of Civil Engineers' survey (Mansell, 2018) demonstrated: while the appetite for SDG reporting at project level is very strong (87%), especially by millennials, only a third of the 325 survey respondents assessed current tools as 'fit for purpose'. The research study identified four Critical Success Factors (CSF) for Measuring Projects' SDG Impacts:

- CSF #1: Strategic Success Definition. Clear understanding of project success – is it about time, cost and scope (doing the projects right) or, is it about outcomes and strategic impacts (doing the right projects), or a balance of both?
- CSF #2: Holistic Performance Measurement tools. The need for tools that could measure traditional outputs of time, cost and scope, as well as more opaque successes, such as outcomes, benefits and impacts.
- CSF #3: Aligned Business Priorities. Balancing competing business priorities, that were perceived to weight ‘profit’ too heavily against ‘people’ and ‘planet’, otherwise known as the ‘Triple Bottom Line’ (Elkington, 1994).
- CSF #4: Strong Leadership. The need for leaders who can galvanise and motivate their teams, capturing their ‘heads and hearts’ to drive forward changed behaviours.

The shortcomings of not having the four CSFs in place, which was the main finding from the survey, represents both a theoretical knowledge gap, and for the practitioner, it results in weaker investment decisions since SDG lessons are not being learned from project delivery successes and failures. The problem is complex and multi-faceted in nature, at both the project and organisational levels. At its core, the most important issue is to understand what defines project success. Too often this has been done by measuring the project management processes of delivering a project to time, cost and scope (and quality), otherwise known as the ‘iron triangle’. But for linkage to the SDGs, there needs to be a broadening of the success definition to become more holistic. To do so, requires a refresh of underpinning theories, specifically in regard to sustainable development.

### *1.1.Sustainable Development Goals*

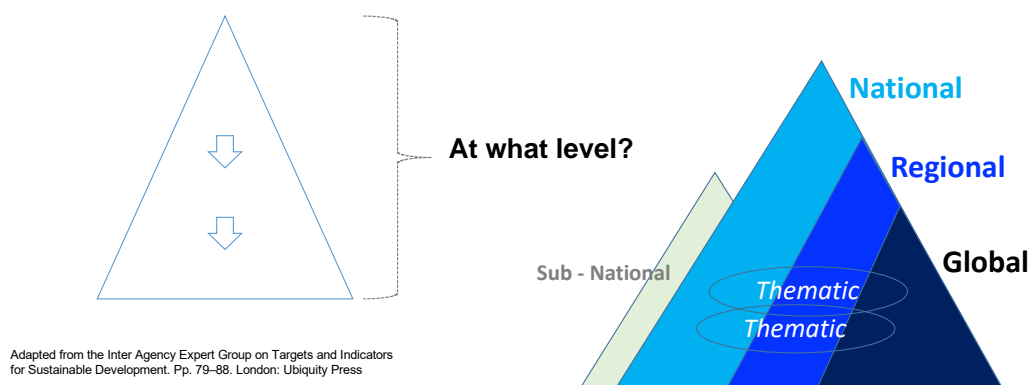
The United Nations’ ‘Transforming Our World’ report (United Nations, 2015) was adopted by 193 states at the United Nations General Assembly. This has provided a globally agreed sustainable development framework consisting of 17 goals (Figure 31) and 169 targets to be achieved by 2030. But progress towards the 2030 targets is perilously slow, especially for the most disadvantaged and marginalised groups (United Nations, 2018). While there have been some significant advances since the Rio Summit (1992 and the ‘+20’ in 2012) and the Kyoto Protocol (2005), such as the transformational technologies for battery-powered cars and renewable energy, even a rise of 1.5°C now appears to be inevitable (UN IPCC, 2018). This temperature rise would potentially wipe out almost all of the world’s coral with hundreds of millions of people potentially killed from the effects of drought and coastal flooding, while the threat of starvation will likely trigger unprecedented mass migration (UN IPCC, 2018).





**Figure 31: The United Nations 17 Sustainable Development Goals (full details can be accessed at <https://sustainabledevelopment.un.org/>). [Usage of graphic agreed by UN]**

The delivery targets are understandably ambitious and needed a reporting framework that would drive meaningful and verifiable progress towards the 2030 targets. In 2017, the UN’s Inter-agency Expert Group on Targets and Indicators for Sustainable Development designed a mechanism that linked goals, targets and indicators across the geographic and governance boundaries at national, regional and global levels (IAEG-SDGs, 2017). Within this framework, shown in Figure 32, the Expert Group designed thematic areas that could also be used at the sub-national level, but because the targets and indicators were originally designed to be used at global, regional and national level, they had reduced applicability at organisational or project levels. Simply stated, ‘one size does not fit all’. This provides a significant challenge because most of the investment needed (USD \$94 trillion) to respond to the global goals (Global Infrastructure Hub, 2018) is delivered through the business sector, typically through infrastructure projects, which contribute to the systems and services that can positively impact health, wealth and inequalities.



Adapted from the Inter Agency Expert Group on Targets and Indicators for Sustainable Development. Pp. 79–88. London: Ubiquity Press

**Figure 32: The SDG Targets and Indicators’ Framework designed by the UN IAEG-SDGs (2017)**

As stated earlier, the SDGs consist of 17 major goals and 169 concrete targets and because some of the targets are not expressed as concrete numbers, the UN also developed a framework of 232 indicators for monitoring and reviewing the targets. Research into the use of the SDG framework (Mansell *et al.*, 2019a) on infrastructure projects has identified that the targets (N = 169) and indicators (N = 232) are too numerous and complicated and therefore unfortunately they are rarely used by engineering practitioners. The research concluded that a new way was needed to reduce the scientific and statistical complexity of the SDG measurement framework. The starting point for this approach, was to evaluate their usability and applicability at the project level on a sector-by-sector basis. For example, in the infrastructure sector, recent analysis (UNOPS, 2018) indicates that 81% of the SDG targets are influenced by infrastructure investment projects. However, ‘influence’ is a comparatively weak word without specifying ‘attribution’ (i.e. directly impacting with verifiable evidence) or ‘contribution’ (i.e. linkage presumed but without evidence), and therefore, despite the positive conclusion from the UNOPS’s analysis (2018), further research is needed to identify which of the SDG targets can be used at project level. This provides a fifth CSF:

**Additional Critical Success Factor for Measuring Projects’ SDG Impacts (#5):** Prioritisation of (a limited) number of SDG targets relevant to the infrastructure project.

The problem of identifying suitable SDG measurement is compounded at the indicator level, where a further 232 measurement metrics reside. For example, the UK’s Office for National Statistics (ONS) online portal, responsible for reporting UK’s progress against global SDG indicator measurement, shows that in April 2019 they only had data for 173 of the 232 indicators, with 69 being without data (ONS, 2019). The ONS’ challenge of collating reporting evidence for the 232 indicators was further corroborated by recent analysis (Mansell *et al.*, 2019a) of the viability of using each of 232 indicators for infrastructure project-level measurement of success. The analysis, based on inductive reasoning using the project success framework proposed by Peter Morris (2013) and Cooke-Davies (2007) and then analysed against the Cost-Benefit measurement framework from the HMT Green & Orange Books (HM Treasury, 2013) and the World Bank Monitoring, Reporting, Evaluation and Learning methodology (Dudwick, *et al.*, 2006), highlighted there were only a small number of indicators (N = 28; 12%) relevant to engineering projects. Of these, only 8% (N = 20) have close alignment with the engineering projects, and 4% (N = 8) have marginal relevance, as shown in Figure 33 below. This analysis highlighted a ‘gap’ of not having suitable indicators below the SDG target level that could be used on infrastructure projects.

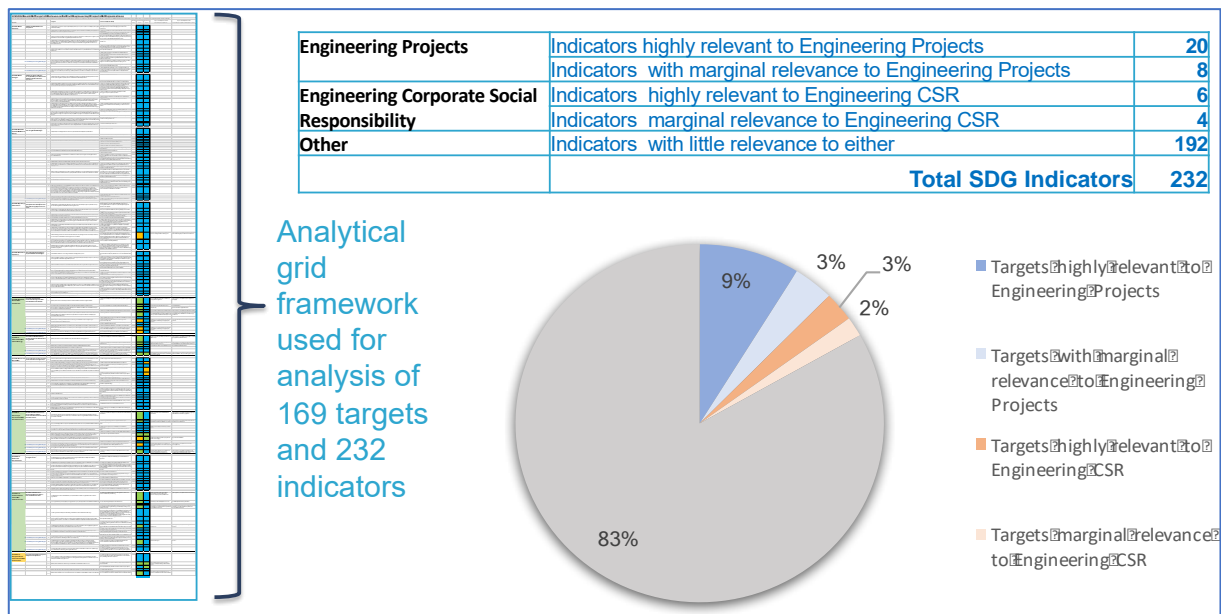


Figure 33: Analysis of the SDG Targets and Indicators' measurability

The results from the research into the SDG indicators highlights a sixth CSF:

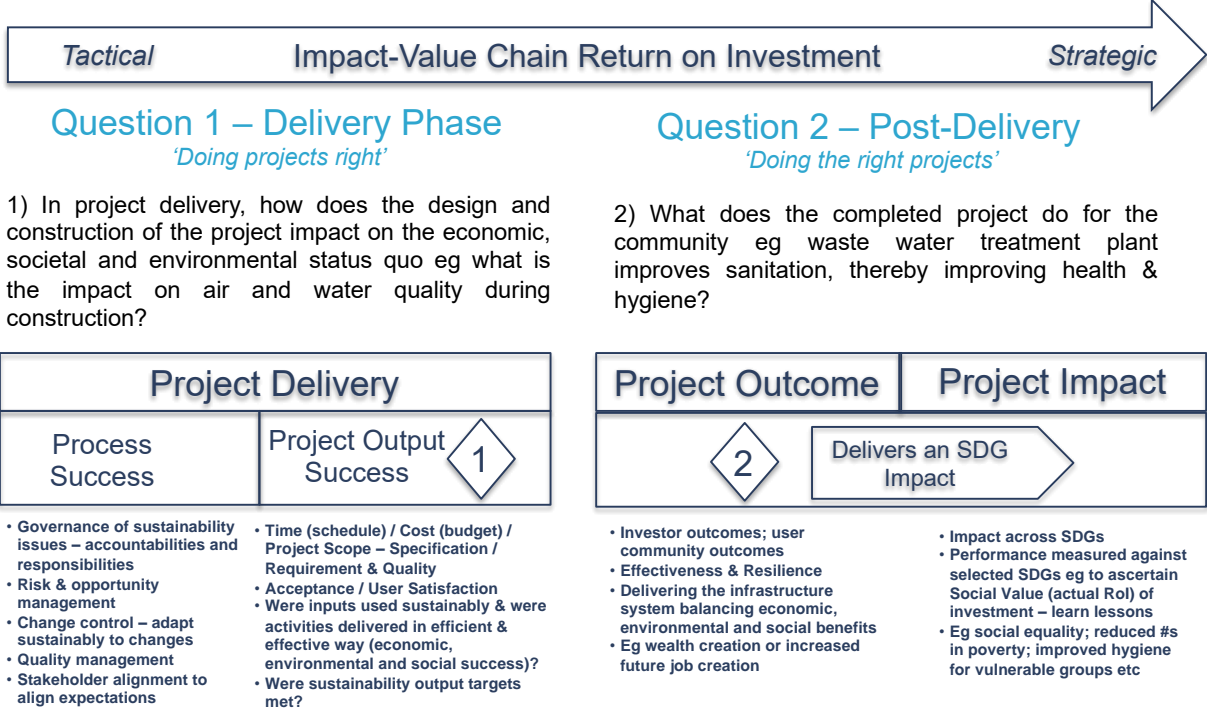
**Additional Critical Success Factor for Measuring Projects' SDG Impacts (#6):**

Selection of (a limited) set of specific infrastructure indicators (not SDG indicators) relevant for infrastructure projects.

*1.2. Project Success*

Before sharing the new process model, it is important to reflect on the different ways of defining project success, particularly since its relevance is linked to two of the original critical success factors: Critical Success Factor #1, Strategic Success Definition; and Critical Success Factor #3, Aligned Business Priorities. While project success is a heavily researched field of study within the field of project management (see for example the work of Thiry, 2004; Müller and Jugdev, 2012), the quantitative analysis of success criteria and their alignment to outputs or outcomes, is less evident. For example, Michael Thiry (2004) highlights that “*too many critical success factors are related to inputs and management processes and not enough on outcomes*”. This is further supported by those (Morris, 2013; Cooke-Davies, 2007) who identify two primary levels of success criteria: project management success – was the project done right? Secondly, project success – was the right project done? To explain the difference, it is helpful to go back to basics – that projects are temporary organisations that have a well-recognised development process, referred to as the project life cycle (Morris, 2017). To achieve its ‘ends’ (post project), the project management team harnesses the ‘ways’ of tools and techniques, and employs practices, processes and procedures, by ‘means’ of a group of skilled individuals. Together the ends, ways and means form a distinct body of knowledge, such as the APM’s and PMI’s Body of Knowledge. There is, however, a fundamental problem that, as a discipline, project management too often defines success by the best use of these practices, instead of what its impact is on producing outcomes of real value (Morris, 2017). This is

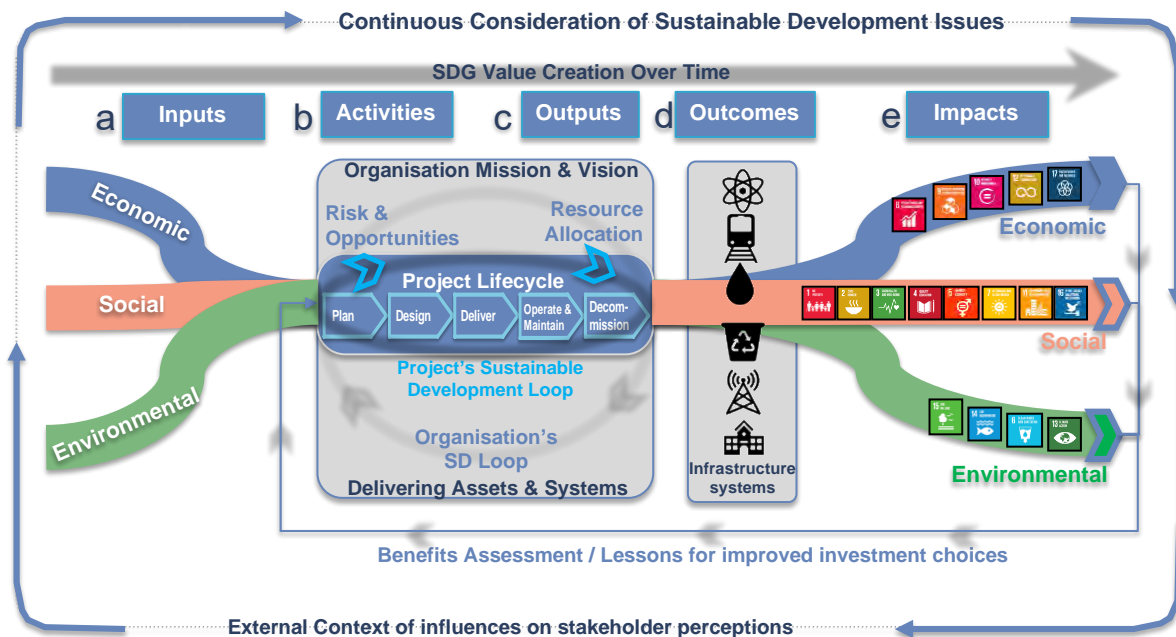
important to resolve because of the huge investment across all projects to effect successful change, especially when related to strategic SDG impacts. The two fundamental parts of defining project success are shown in Figure 34 below. The first question is focused on the delivery phases and is tactical in nature, while the second seeks to define the longer-term outcomes and impacts, that are more strategic in orientation.



**Figure 34: Framework for sustainability and project success reporting. The two core sustainable development questions at project level.**

*1.3. Infrastructure SDG Impact-Value Chain (IVC) process model*

Having defined the different ways of classifying project success, a new SDG project transformation process model was developed for the infrastructure sector (Mansell et al., 2019b). It provides the ‘lens’, called the *SDG Infrastructure Impact-Value Chain (IVC)*, to analyse whether there is evidence of a ‘golden thread’ between best practice sustainability reporting frameworks at project level, with those at strategic-level SDG impacts. The IVC model (Figure 35) is based on four underpinning theoretical models including: 1) The Theory of Change (Weiss, 1995; Stein and Valters, 2012); 2) Creating Shared Value (Porter, 1985, 2011); 3) Infrastructure Systems approach (Hall et al., 2016; Thacker and Hall, 2018); and, 4) the Triple Bottom Line (Elkington, 1994, 2013, 2018; Griggs et al., 2013). The last of these, the TBL, provided the link to SDGs through a more holistic ‘systems approach’ to address infrastructure sustainability in the SDG context. The IVC provides a new holistic method to potentially improve sustainability on projects and programmes by guiding decision-makers in their investment choices through confidence that they link to specific SDG targets.



**Figure 35: The Infrastructure SDG Transformation Process Model – The Impact-Value Chain (IVC).** Adapted from ICAS/IIRC’s ‘The Sustainable Development Goals, integrated thinking and the integrated report’ (Adams, 2017).

In practice, the golden thread (the TBL thematics of economic, social and environmental) shown in Figure 35, can be used to map the TBL against the five stages of the IVC as shown in Table 27 (with columns a-e also represented in Figure 5). The examples provided indicates that there are clear ‘Theory of Change’ patterns that build through the iterative stages and this can be linked directly to project and organisational level understanding of sustainability reporting.

	Input	Activity	(c) Output	(d) Outcome	(e) Impact
Economy	Finance / investment; insurance; risk contingency allocations; WLC analysis; stable government; non-corrupt financial context.	Job creation; income; wages; source, move & assemble materials; build iteratively through defined activities such as early earthworks; local & wider supply chain activity	Project completion to time/cost/scope – bridge, building, road etc; income; profit; taxes from in-project business; Net Present Value provides strong RoI against Whole Life Costs.	Economic growth enabled by completed assets as a system; more resilience; wealth creation; ownership; increased future investment and additional job creation.	SDGs 8, 9, 10, 12
Social	People; social networks; cultural and technical knowledge; listening &	Collaborative innovation; health & wellbeing; stakeholder engagement; skills and	Asset’s social utility; meeting stakeholders’ objectives; individual and group learning; reinforced	Infrastructure enabled change across health, education, etc., e.g. reduced mortality; gender equality;	SDGs 1,2,3,4,5,7, 11

	working with stakeholders.	learning; working conditions; production activity; user engagement.	community stakeholder groups.	social equity; justice; post project knowledge sharing.	
Environment	Raw materials; land take; water; light; clean air; energy; planned land use; ecology ecosystem valuation assessment.	GHG emissions; pollution; noise and air quality; works' affects pre and during production eg waste management, nitrogen, carbon dioxide, acidification levels.	Managed effects on completion of asset; replanted trees etc; improved local area; no net loss on eco system footprint; short term environmental targets met.	Restored/ improved biodiversity and natural balance e.g. increased long-term positive effect on environment through improved sustainability.	SDGs 6,13,14,15

Table 27: IVC Table illustrating Golden Thread mapping of the TBL with the 5 stages of the IVC.

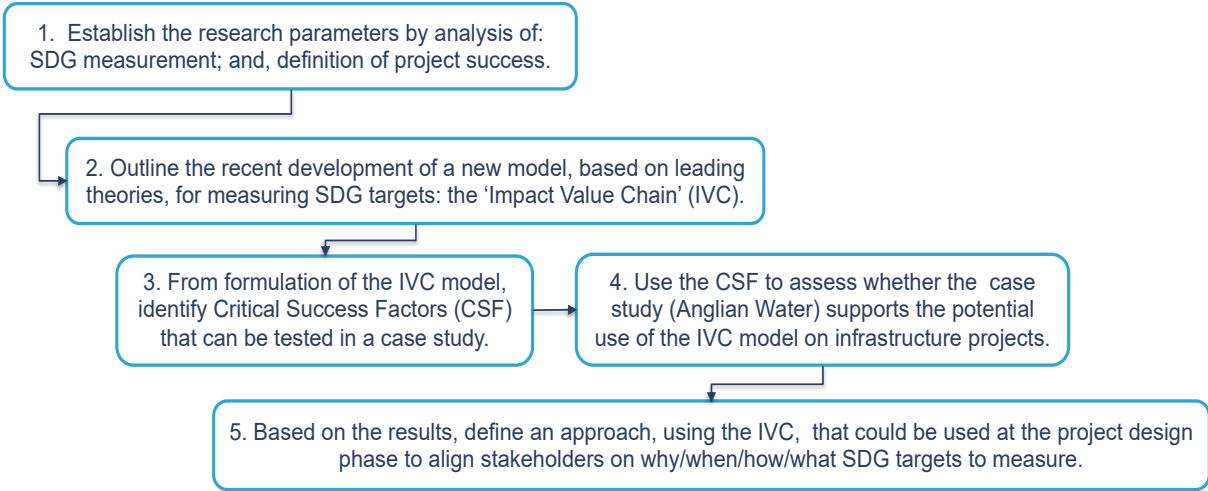
The data in Table 27 provides the conceptual basis for proposing that there is a golden thread that links tactical success during delivery, to the strategic success embodied in the post-project outcomes and SDG strategic impacts.

The next section uses a case study of a UK water utility company, Anglian Water, to demonstrate how the IVC process model can integrate the 'Triple Bottom Line' to ensure balanced definition of success across economic, environmental and social thematic. The emphasis is switched from 'doing projects right' to 'doing the right projects', both are important, but the latter is critical. This is an explicit part of the IVC model, ensuring that short-term project success measures are balanced with post-project longer-term outcomes and SDG strategic impact, which many (Morris, 2013; Cooke-Davies, 2002 and 2007) have suggested are improved definitions of project success.

## 2. Methods

The research team's method was based on using a case study investigation to test and validate the application of SDG measurement on infrastructure projects. The starting point, as shown in Figure 36, was to establish the parameters of the research, briefly outlining the SDGs and the challenge of measuring goals, targets and indicators at project level. It then evaluated the definition of project success and the difference between 'doing projects right' and 'doing the right projects'. This led to the proposed Infrastructure SDG Transformation Process Model, called the '*Infrastructure SDG Impact-Value Chain*' (IVC) (Mansell, 2019b), that links tactical-level project delivery with global-level strategic SDG impacts. In the process of this analysis, it identifies six 'Critical Success Factors' (CSF), that are evolved from the four CSF in the survey, each with its own underpinning question. These CSF questions are then tested against the case study of Anglian Water, a water utilities company that has started the process of embedding SDG reporting at both organisational and project levels. Finally, the results from

the case study enable an approach to be defined, using the IVC, that could be used at the project design phase to align stakeholders on why/when/how/what SDG targets to measure.



**Figure 36: Research methodology employed.**

As shown in steps three and four, the case study analytical approach was structured to investigate the four CSF’s that were identified from the survey (Mansell, 2018) and the two additional CSF’s that have been identified from the development of the IVC model (Mansell et al., 2019b), as shown in the composite CSF table below (Table 2).

Category		Critical Success Factors for SDG Measurement	Derivation
CSF Enablers	1	<b>Strong Leadership.</b> What is the role of leadership to champion the SDG impacts across the TBL?	From Engineers’ survey (Mansell, 2018). Identified as #4 critical success factor.
	2	<b>Clarity of IVC project success definition.</b> Do businesses have a clear understanding of the need to separate definition of success between ‘in-project’ inputs/activities/outputs and ‘post-project’ outcomes and impact?	From Engineers’ survey (Mansell, 2018). Identified as #1 critical success factor.
CSF for selection and reporting SDGs	3	<b>Step 1 - Prioritising SDG goals aligned to Strategic Vision.</b> Do businesses have a clearly defined strategy that can guide the prioritisation of SDG goals? The ‘Ends, Ways, Means’ model requires clarity of the ‘ends’ prior to defining project success (in-project and post-project). See column ‘e’ in Table 27.	From Engineers’ survey (Mansell, 2018). Identified as #1 and #3 critical success factor.
	4	<b>Step 2 - Select targets relevant to the project.</b> Which SDG goals and which relevant targets are selected at project level to measure impact? Prioritisation of (a limited) number of SDG targets relevant to the infrastructure project.	From SDG analysis (Mansell et al., 2019a) and identified in this paper as #5 and #6 critical success factor.
	5	<b>Step 3 - Aligned Business Priorities / Integrate the targets across the TBL.</b> How are the project success criteria balanced across the Triple Bottom Line – what trade-offs are made?	From Engineers’ survey (Mansell, 2018). Identified as #3 critical success factor.
	6	<b>Step 4 - Reporting and communication.</b> Are the tools available for holistic measurement of success? What is the best way to share data on SDG progress, internally and externally?	From Engineers’ survey (Mansell, 2018). Identified as #2 critical success factor.

**Table 28: Critical Success Factors (CSF) for embedding SDG target measurement at project level.**

The central investigation was to test the new IVC model against current practice using the example of one of UK’s largest water utility companies, Anglian Water. It is amongst UK’s leading sustainability and sustainable development reporting pioneers (with early use of SDG targets) and was the winner of Business in the Community’s (BITC) Responsible Business of the Year Award in 2017. This recognised Anglian Water's ambitions laid out in its ‘Love Every Drop’ (of water) vision, which aimed to create a resilient environment that allowed sustainable growth and the ability to cope with the pressures of climate change.

The data for the case study was accessed by interviewing (1.5 hours) a senior Anglian Water executive, Chris Newsome OBE, who at the time was the Director for Asset Management. A second interview was held with the Head of Anglian Water’s Sustainability Management, as a further source of data and information. Mr Newsome is also the Chair of the UK Government’s Green Construction Board’s Infrastructure Working Group and has been a major sponsor and champion of the sustainable development programme across Anglian Water as well as the infrastructure sector more generally, for the past 10 years. Mr Newsome provided publicly-available documents (i.e. as a form of secondary research) to support the in-depth insights into the company’s pioneering work in sustainable development. This research was triangulated by further review and evaluation of the company’s website and related documents as well as social media on the company’s approach to sustainable development in order to verify the data validity.

### 3. Results

Case Study Investigation: Anglian Water – Organisational Focus on Sustainable Development. [Permission granted for re-use of data and images by interviewees and organisation]

The Anglian Water approach to sustainability and the SDGs is explained in their Annual Integrated Report (Anglian Water, 2018a). The report includes a description of their impact-value objectives (performance against outcomes) assessment which correlates with the Triple Bottom Line of the economic, social and environmental thematic. In summary, Anglian Water (AW) describe their TBL priorities as follows (Table 29).

Anglian Water Outcomes	Objectives
<b>1. Smart Business.</b> Innovating by exploring new ways to operate more sustainably and helping customers, business partners and employees to embrace our Love Every Drop strategy.	<ul style="list-style-type: none"> <li>i. Resilient business</li> <li>ii. Investing for tomorrow</li> <li>iii. Fair charges, fair returns</li> <li>iv. Our people: healthier, happier, safer</li> </ul>
<b>2. Smart Communities.</b> Collaborating and engaging with customers, colleagues and business partners, and inspiring them to take positive steps	<ul style="list-style-type: none"> <li>i. Positive impact on communities</li> <li>ii. Safe, clean water</li> </ul>



towards achieving our vision for a sustainable future.	iii. Delighted customers
<b>3. Smart Environment.</b> Transforming behaviours by playing a leading role in reshaping how society values and uses water and reducing our combined impact on the world around us.	i. A smaller footprint ii. Flourishing environment iii. Supply meets demand

Table 29: Anglian Water’s Performance against Outcomes.

These are shown below in the images from the Annual Report (Anglian Water, 2018a, pages, 24-25, 29) (Figure 37).



Figure 37: Anglian Water alignment of purpose-outcomes and SDGs (Anglian Water, 2018a). [Permission to re-use agreed by AW]. (for illustrative purposes only)

The following analysis of the case study is structured according to each of the CSF titles. The data is shown in the form of key quotes from the Director for Asset Management for the company, supported by data gathered from open source documents.

### 3.1 CSF1: Strong Leadership. What is the role of leadership to champion the SDG impacts across the TBL?

Consistent with the survey results (Mansell, 2018), Anglian Water place a high priority on leadership to galvanise commitment to their corporate level sustainability objectives. They achieve this through consistent and strong communications, both graphically, such as through their ‘Purpose Wheel’ (Figure 38), and by the high profile championing of their sustainable development approach by their Board and Executive.



**Figure 38: Anglian Water Purpose Wheel (Anglian Water, 2018a) aligned to the Triple Bottom Line. [Permission to re-use the wheel agreed by AW].**

Mr. Chris Newsome, a Director and Executive Board member at Anglian Water, observed [note: in future, all quotes from the interview are labelled as ‘CN’ followed by the quotation]: *“Leadership is the most important critical success factor, both internally and externally, to align and galvanise our employees, our communities and the supply chain. It was about getting us all to be more collaborative in finding novel, innovative ways of delivering sustainable solutions ... It’s about the leaders capturing the hearts and minds of the stakeholders to champion changed behaviours to achieve big, bold strategic outcomes.”*

In his view, it played an important part in Anglian Water becoming a sustainable development leader across the sector. CN: “there are a number of reasons why we won Business in the Community’s (BITC) Responsible Business of the Year Award in 2017 – but a key part was that our CEO brought a very specific challenge back to the business having been inspired by a ‘Seeing is Believing’ visit, organised by BITC, to an area near the Olympic Park in London. The visit looked at how businesses were able to create opportunities and skills for those living in areas of high deprivation and low social mobility. The CEO’s response was... ‘how can we do something on a similar scale, in the region we serve, to make a real difference?’. This led to our hugely successful programme in Wisbech and helped us develop an approach that we’ve subsequently used on project work in Nepal alongside Water Aid.”

[Note: The Wisbech project, illustrated in detail in Table 31, was a forerunner of the Lahan project in Nepal. Lahan was the first WaterAid project with significant engagement from the Utilities’ supply chain and became a beacon to demonstrate how such projects can be driven across Nepal and beyond.]

He also notes the moral values that are implicit in the choice of making sustainable development a core business priority for Anglian Water. CN: *“a vital part of leadership is doing the right thing, just because it is the right thing to do, not because of a box-ticking exercise”*. He expands this to state, CN: *“Our leadership was engaging the supply chain proactively, to collaboratively change the way we thought about, and did, our business...we*

*wanted the approach to become part of the way we jointly became leaders in delivering our businesses successfully... We wanted to establish meaningful change across the supply chain, and we recognised that to do this, we had to develop long-term relationships, hence we contracted on a five, plus five, plus five-year basis. This built longevity into our thinking and allowed true innovation to develop solutions to the bigger sustainable development issues across the environment – driving efficiency and effectiveness.”*

This was not necessarily an approach that was either quick or easy and needed a tough commitment from the leadership, CN: "It's fifty percent belief and fifty percent belligerence, when you start something like this; That is holding yourself and others to account. That's what I mean by belligerence. In other words, 'seeing it through'."

The core principles of governance (OECD, 2015) of accountability, responsibility and transparency were also noted, CN: “a key part of the leadership is the ownership of the sustainable development strategy. It is also about accountability and having the resources to deliver the solution. That is why the ‘Infrastructure Clients’ are the single most important stakeholders in addressing sustainable development. If they ‘own’ and champion the solution, then the supply chain will follow... hence leadership and procurement are the biggest elements of the recent Green Construction Board’s ‘Three Years On Report – Reducing Carbon Reduces Cost’ report” (Green Construction Board, 2015).

*3.2.CSF 2: Clarity of IVC project success definition. Do businesses have a clear understanding of the need to separate definition of success between ‘in-project’ inputs/activities/outputs and ‘post-project’ outcomes and impact?*

In the Anglian Water Integrated Report 2018, (Anglian Water, 2018a, p.8), the CEO says: “We are continuing to plan and to invest in protecting customers and the environment. This year saw the publication of our draft Water Resources Management Plan, which sets out how we propose to balance supply and demand in a fast-growing region over the next 25 years and to protect customers from severe water restrictions in a future drought.” The Annual Report highlights that Anglian Water explicitly assesses both the short-to-medium term economic factors that their investors value, as well as the longer-term strategic sustainable development impacts that are more aligned to SDG targets.

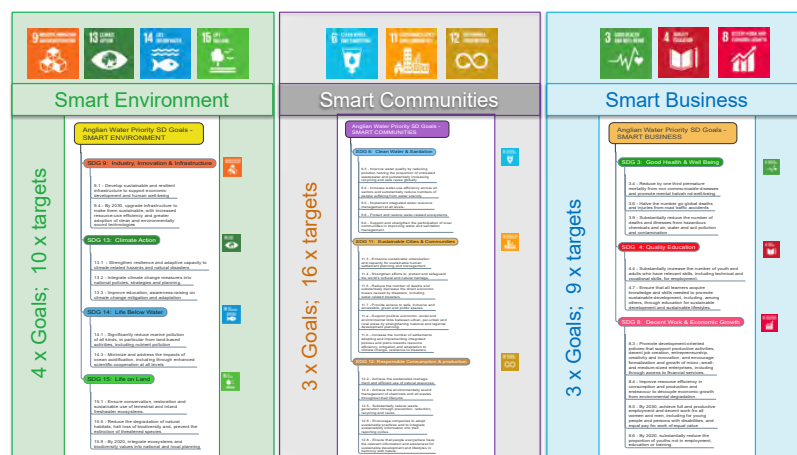
Chris Newsome explains how Anglian Water used the overall ‘Love Every Drop’ banner campaign to balance long-term and short-term priorities, CN: “*In 2015 we refreshed our ‘Love Every Drop’ goals and aligned them with the Outcomes Wheel shown in the Annual Report. So, we thought long and hard about, not just the goals that we created, but how did that fit with a set of longer-term outcomes in our region and what that would look like in terms of implementation. This was our way of meaningfully connecting the strategy with outcomes that our stakeholders recognised.*”

It was also noted, that Anglian Water uses simple and accessible language (see CSF 6 on communications) to explain their ‘Purpose Wheel’ and its linkage to Outcomes-Impacts. This aligns with the IVC model and indicates a viable way of thinking ‘big and long’, whilst managing the activities and outputs on a short-term basis to track progress.

3.3.CSF 3: *Prioritising SDG goals aligned to Strategic Vision. Do businesses have a clearly defined strategy that can guide the prioritisation of SDG goals? The ‘Ends, Ways, Means’ model requires clarity of the ‘ends’ prior to defining project success (in-project and post-project).*

The Anglian Water approach aligns closely with the IVC model, since it also uses an ‘Ends, Ways, Means’ logic, similar to the Theory of Change concept (Figure 35), CN: “*you must start with the end in mind, even if you haven’t got a detailed routemap to deliver at every stage of the journey. Part of the mantra is to set big audacious goals and then adopt an attitude of ‘I’ve started so ill finish’ and by the way, you never actually finish, because the end goal is moving, its like you achieve one peak, but realise it is a false horizon, and so you continue your climb to the next summit.*”

As well as the ten prioritised goals, Anglian Water have also prioritised 35 targets that are most easily measured at project level, which are reproduced below (Figure 39).



**Figure 39: Anglian Water has three business priorities that are balanced across the Triple Bottom Line. The specific SDG targets (N = 35) in this figure are reproduced in readable format in Table 30. (for illustration only)**

The value of having clarity of the strategic ends, is noted, albeit with a caution that the identification of targets for tracking performance must not become a ‘box-ticking’ exercise that distorts clarity of outcomes, CN: “*if you actually begin with the end in mind of the outcome you're seeking and how you wire your DNA to achieve that, you are far more likely to achieve those outcomes, and in so doing the boxes get ticked. But if you predicate your thinking with thoughts about just filling the boxes, you've constrained yourself.*”

Therefore, to overcome the box-ticking mentality, CN explained their approach: “Anglian Water thought long and hard about its position in the region and how we contributed strategically as a major player in the region and we created the concept of 'Love Every Drop' and in essence, our own SDGs, to align our strategy with local outcomes ... We used the ‘Love every Drop' goals to identify ambitious aspirations, which meant that our business had to think longer term.”

3.4.CSF 4: Select targets relevant to the project. Which SDG goals and which relevant targets are selected at project level to measure impact? Prioritisation of (a limited) number of SDG targets relevant to the infrastructure project.

The chart in Figure 39 illustrates the 35 targets selected by Anglian Water, which at first sight is impressive, but the interview identified that it is challenging to move beyond the rhetoric of great sounding qualitative statements. Therefore, it is important to agree and publish, hard quantitative targets that success of the organisation can be assessed against, CN: "... so we nailed our colours to the mast and started reporting against those. One of them was to take 50 percent of the carbon out of the assets we build by 2015. It was the one that had a specific date on it and a specific quantity, and I deliberately did that because I believed it and I was belligerent enough to drive it.... that's the one that perhaps, out of all sustainability targets and goals, that Anglian Water had the greatest recognition from and probably reflects the greatest change program that's gone on across the whole of the supply chain."

Anglian Water Priority SD Goals and Targets	WSE	Waste 2020 Vision	Drop CO2	Every Drop Counts - Stop	USA Centre for Water Studies	bc-1	Building Resilient	bc-2	Community Education	Customer Management	Business in the Community	Biodiversity	Natural Capital	Keep Clear	Water Efficiency	Wasteland	Wasteland West	Wt. Smart	Waterparks	#BiginWh	Green Construction	PRG Small	Sales & Mkt	LIFE	Full-on Main	Coaster	Penetration	The College Westleigh	Total				
<b>SMART COMMUNITIES</b>																																	
<b>SDG 6: Clean Water &amp; Sanitation</b>																																	
6.3 - Improve water quality by reducing pollution halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally										1					1																9		
6.4 - Increase water-use efficiency across all sectors and substantially reduce numbers of people suffering from water scarcity	1																														2		
6.5 - Implement integrated water resource management at all levels	1						1																								2		
6.6 - Protect and restore water-related ecosystems																	1	1													3		
6.7 - Support and strengthen the participation of local communities in improving water and sanitation management																															0		
<b>SDG 11: Sustainable Cities &amp; Communities</b>																															9		
11.2 - Enhance sustainable urbanisation and capacity for sustainable human settlement planning and management			1	1																											2		
11.4 - Strengthen efforts to protect and safeguard the world's cultural and natural heritage										1																					1		
11.5 - Reduce the number of deaths and substantially decrease the direct economic losses caused by disasters, including water-related disasters							1	1																							2		
11.7 - Provide access to safe, inclusive and accessible, green and public spaces																															1		
11.a - Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning																															1		
11.b - Increase the number of settlements adopting and implementing integrated policies and plans towards resource efficiency, mitigation and adaptation to climate change, resilience to disasters																															1		
<b>SDG 12: Responsible Consumption &amp; production</b>																															6		
12.2 - Achieve the sustainable management and efficient use of natural resources																															2		
12.4 - Achieve the environmentally sound management of chemicals and all wastes throughout their lifecycle																															1		
12.5 - Substantially reduce waste generation through prevention, reduction, recycling and reuse																															1		
12.6 - Encourage companies to adopt sustainable practices and to integrate sustainability information into their reporting cycles																															1		
12.8 - Ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature																															1		
<b>SMART BUSINESS</b>																																	
<b>SDG 3: Good Health &amp; Well Being</b>																																5	
3.4 - Reduce by one third premature mortality from non-communicable diseases and promote mental health and well-being																																1	
3.6 - Halve the number of global deaths and injuries from road traffic accidents																																2	
3.9 - Substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination																																2	
<b>SDG 4: Quality Education</b>																																3	
4.4 - Substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment																																1	
4.7 - Ensure that all learners acquire knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles																																1	
<b>SDG 8: Decent Work &amp; Economic Growth</b>																																8	
8.3 - Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services																																2	
8.4 - Improve resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation																																2	
8.5 - By 2030, achieve full and productive employment and decent work to all women and men, including for young people and persons with disabilities, and equal pay for work of equal value																																2	
8.6 - By 2020, substantially reduce the proportion of youths not in employment, education or training																																2	
<b>SMART ENVIRONMENT</b>																																	
<b>SDG 9: Industry, Innovation &amp; Infrastructure</b>																																	10
9.1 - Develop sustainable and resilient infrastructure to support economic development and human well-being																																5	
9.4 - By 2030, upgrade infrastructure to make them sustainable, with increased resource efficiency and greater adoption of clean and environmentally sound technologies																																5	
<b>SDG 13: Climate Action</b>																																	4
13.1 - Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters																																2	
13.2 - Integrate climate change measures into national policies, strategies and planning																																1	
13.3 - Improve education, awareness-raising on climate change mitigation and adaptation																																1	
<b>SDG 14: Life Below Water</b>																																	4
14.1 - Significantly reduce marine pollution of all kinds, in particular from land-based activities, including nutrient pollution																																2	
14.2 - Monitor and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels																																2	
<b>SDG 15: Life on Land</b>																																	9
15.1 - Ensure conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems																																3	
15.5 - Reduce the degradation of natural habitats, halt loss of biodiversity and prevent the extinction of threatened species																																3	
15.9 - By 2020, integrate ecosystems and biodiversity values into national and local planning																																3	
	10	6	2	4	2	3	2	1	4	5	3	3	4	1	1	1	1	1	2	1	4	1	1	1	1	1	1	1	1	1	67		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27						

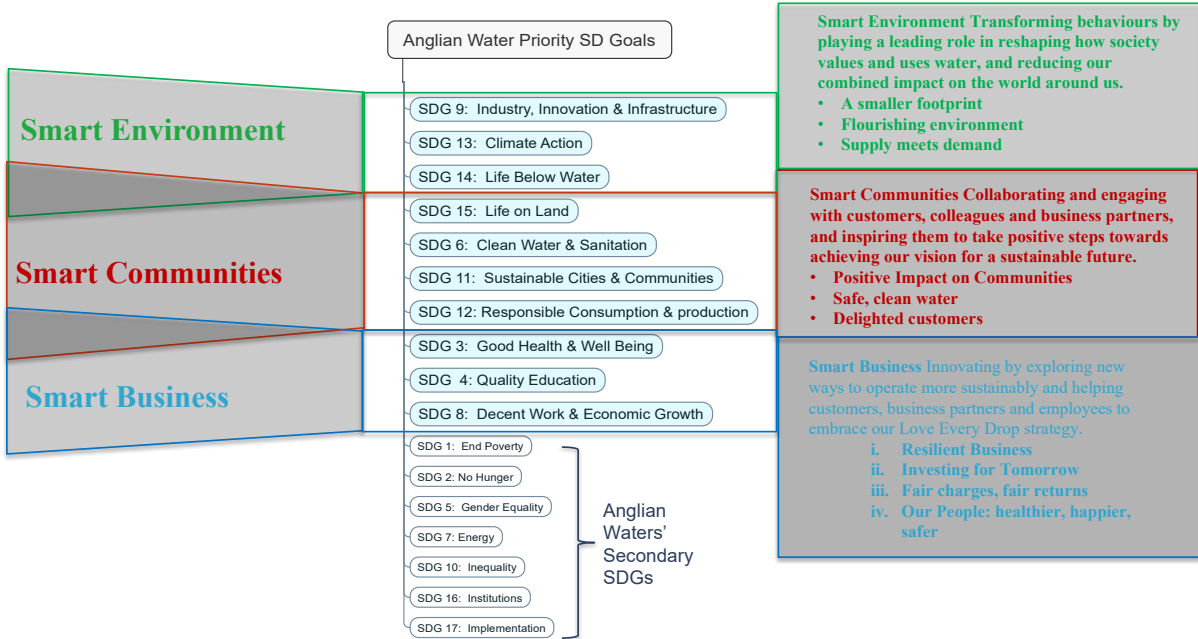
Table 30: Anglian Water’s Mapping of SDG Targets to the 27 Projects. The y-axis shows the 35 SDG targets selected at Anglian Water corporate level; the x-axis shows the 27 projects that they are allocated to by AW. (for demonstration only)

The representation shown in Table 30, of mapping Anglian Water’s top 27 projects to their prioritised SDG targets, shows that all projects had at least one target to measure success

against, while one project had 10 targets to map success against. This mapping by Anglian Water highlights that only a few targets can realistically be measured at project level. It also suggests that if the targets are measured across a portfolio of projects and programmes, then a composite SDG impact measurement could be made. This would provide useful insights to support investment appraisals that seek to better understand the strategic impacts of investments and their broader TBL's Return on Investment.

*3.5.CSF 5: Aligned Business Priorities / Integrate the targets across the TBL. How are the project success criteria balanced across the Triple Bottom Line – what trade-offs are made?*

A representation of the linkage of the Anglian Water three TBL thematic outcomes, aligned to their ten prioritised SDG goals, is shown below:



**Figure 40: Anglian Water has three business priorities that are balanced across the Triple Bottom Line.**

In the Anglian Water Integrated Report 2018, (AW, 2018a, p.9), the CEO, Peter Simpson says: “Since becoming Responsible Business of the Year, we have been working hard to show others how sustainability makes good business sense.” This quote emphasises the Anglian Water experience that aligns with the Creating Shared Value (Porter, 1985 and 2011). It implies that the TBL can be balanced – a strategy that focuses on the environment and society, which can equally achieve economic success. When in harmony, real growth is delivered to the benefit of all, as shared by CN: “For example, our approach to ‘product lifecycle management’ was learned from the aeronautical and automotive industry from 2004-5 and this meant that we looked at the whole life costs, which not only ensured we were more outcomes focused, but by the way, improved our productivity by three percent each year, year on year, highlighting that good sustainable development also made good business sense.”

### *3.6.CSF 6: Reporting and communication. What is the best way to share data on SDG progress, internally and externally?*

It has already been noted that Anglian Water had a policy of thinking long-term, explaining their sustainable development approach in accessible language, and also, the need to uphold strong governance principles of accountability and transparency (OECD, 2015). This has led to a strong ethic of being held accountable for delivering meaningful change, including publishing their strategic objectives in quantifiable terms (such as the carbon figures noted in the paragraph above) as well as, equally importantly, the results, CN: *“learning from the likes of Marks and Spencer's Plan A, we realised you had better publish your sustainability plans and outcome targets so that you are kept honest in the process - there is very little point nailing your colours to the mast and then not living to the high expectations ... so the message was that we must commit to do the things that matter to us. That is what gets people excited, because it really matters. We are tough on ourselves on reporting what happens, and this allows us to measure what impact we are having so that we can measure the benefit.”*

The theme of honesty and allowing stakeholders to hold the Executive and Board to account is a powerful lesson that also relates to measuring SDG impacts at project level, CN: *“But the point about turning your ambitious goals into reality, to avoid superficial statements, is that it is all recorded - it is published annually; which is an important part of defining where you are going. Driving towards it with no 'U' turns when some tough decisions have to be made. It's obvious that you have to make loads of tough decisions rather than duck them, and then, recording your progress in an open and visible way, helps keep you honest in that process.”*

A cautionary note about communication was that the messaging should be kept simple and accessible, CN: *“We found that our campaign and collaborative working with partners had created a different conversation with different language. Ultimately, accessible language on meaningful outcomes are what people can buy into and this is what creates the momentum of changed behaviours...Through engagement, innovative solutions address the big problems, Wisbech is an example of working with the community to achieve meaningful long-term changes.”*

### *3.7.Overview Analysis of Anglian Water's projects set against the IVC Framework*

The reference to Anglian Water's Wisbech project in the previous quote, provides a holistic test against the six critical success factors, and a useful way to cap the case study analysis. The table below mirrors the formatting of the IVC table (Table 27) and has been updated with data from the Wisbech Project (Anglian Water, 2018b). This provides a clear assessment as to whether projects could have both the 'in-project' successes measured as well as the 'post-project' outcomes and SDG impacts. It should be noted that the Wisbech project is an outreach community programme inspired by HRH Prince of Wales' 'Seeing is Believing' initiative, that seeks to find ways to support marginalised communities.

	Input	Activity	Output	Outcome	Impact
Economy	Secunded a Senior Operational Manager to Wisbech in 2013; agreed support from other supply chain partners to become involved in the project; this allowed the cost, expertise and effort to be shared across a broad range of partners.	Worked jointly with the local Fenland District Council to develop a longer term strategy beyond their existing 2020 Vision, which was thought to be too short-term to encompass the ‘big, hairy, audacious’ strategic goals that could achieve transformational change; building a business case for the ‘Garden Town’ that would attract investment and large transport infrastructure improvements.	Championing apprenticeships and training scheme with 20 trained and employed year on year; turn the community centre from a £30k pa loss making entity to a vital community hub fuelling future economic success; a confirmed lease and implemented the creation of the ‘Jobs Fair’ and the ‘Jobs Café’; The campaigning body for getting rail back – now in the County Transport Plan.	Bills, affordability and profits to stimulate and sustain the local economy, especially those on lower incomes (bills have only increased by 10% since 1990). Viability of future rail and integrated transport system attracting more regional investment and raising local people’s aspirations; Market Town proposal, with planning for over 10,000 new homes, providing ‘scale of growth’ confidence.	SDGs 8, 9, 10, 12
Social	Started by listening – to understand the local issues from the local community’s perspective; Brought together senior leaders from ‘The @One Alliance’; creating a collaborative multi-stakeholder approach; focused on building	Collaborative innovation with the local community in open and honest talks; health & wellbeing; stakeholder engagement; skills and learning; working conditions; production activity; user engagement; keeping the local community at the heart of the project plans	Providing a community centre (refurbishment of the Queen Mary Centre) that is the hub of employment opportunities; active STEM subjects engagement with schools; specifically focus efforts on helping those not in employment, education or training; untapped	Achieving ‘Business in the Community’ outcomes such as regeneration; Building on the ‘Seeing is Believing’ community initiatives; Understanding the value of long-term thinking; Providing safe, clean and reliable water; Improve the town/regions standing as the	SDGs 1,2,3,4,5,7,11



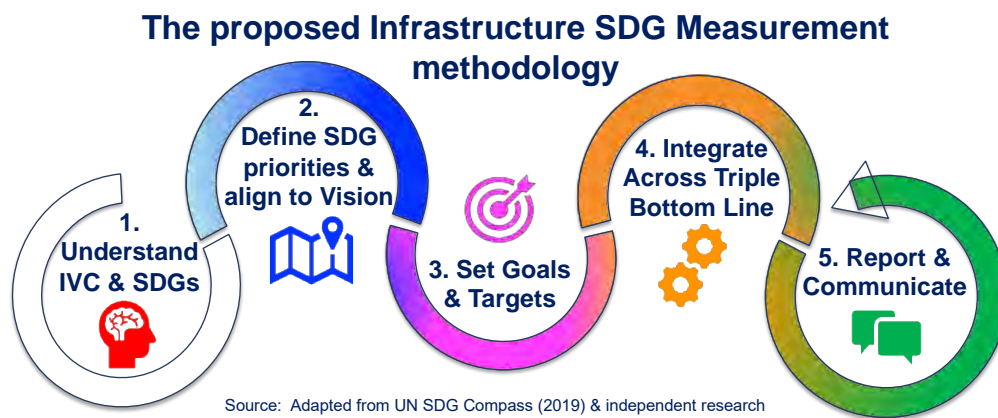
	long-term sustainable relationships with the local community.	and delivery; worked with the College of West Anglia to train more mechanical and electrical engineers; designed and ran new courses; providing IT support from partners to raise aspirations of unemployed.	unused human resource; organised the BITC ‘Big Connect’ event align business connectors from across UK; a second phase for the Queen Mary community Centre to include theatres and a music teaching centre.	6 <sup>th</sup> worst ranked town on social mobility index in UK; addressing the life expectancy that was 3 years less than in Cambridge.	
Environment	Raw materials; land take; water; light; clean air; energy; planned land use; ecology ecosystem valuation assessment.	Management plans for the flood risk, building resilience into engineering designs; using innovative modelling techniques developed by the Dutch government.	A commitment to protecting and restoring our wealth of wetland habitats. make a difference to rare and common species, be they in wet grasslands, open water, fens, or mires.	Build resilience to cope with future challenges. Protecting the environment, we live in; Through its Flourishing Environment Fund, helps environmental organisations deliver real benefits for nature.	SDGs 6,13,14,15

Table 31: Applying Anglian Water’s Wisbech Project initiative to the IVC Grid with mapping of the TBL with the 5 stages of the IVC (data accessed from open source material on website and printed material).

#### 4. Discussion of Findings

The results of the case study investigation have showed that there is a verifiable link across the IVC of activities-inputs-outputs during the ‘in-project’ phase, connecting to the ‘post-project’ outcomes and SDG impacts. A number of Anglian Water’s projects were mapped to this schematic (although for brevity only one, Wisbech, is reproduced in this paper) and this gave confidence that the approach could have wider applicability. Therefore, the results led to a proposed methodology for project leaders to use as a way of strategically aligning stakeholders on a common definition of success, linking tactical ‘in-project’ success of outputs, with the more strategic outcomes and SDG impacts ‘post-project’. The methodology would ideally be used during the design phase of the project. The emphasis is switched from ‘doing projects right’ to ‘doing the right projects’. It includes selection of longer-term outcomes and strategic SDG impacts – which it is suggested offer improved definitions of project success.

The five proposed steps, that have emanated from the six critical success factors that were used as a framework for the case study, are proposed as a way to initiate the ‘right project’ in the ‘right way’ – and with increased clarity of ‘Ends, Ways and Means’.



**Figure 41: The proposed Infrastructure SDG Measurement Methodology derived from the six critical success factors and the application of the IVC model to the Anglian Water case study.**

## 5. Conclusions and Future Work

The central investigation in the case study of Anglian Water was to test and validate whether the new Infrastructure Project Transformation Process Model, called the ‘*Infrastructure SDG Impact-Value Chain*’ (IVC), could link tactical-level project delivery with global-level strategic SDG impacts. The study used the ‘golden thread’ of the TBL thematic areas (namely economic, social, and environmental) to interrogate whether one of UK’s leading water utility companies, Anglian Water, was already delivering strategic sustainable development solutions that could be mapped to SDG targets. The case study investigation has resulted in a proposed methodology for project leaders that can be used as a strategic-level tool to link tactical ‘in-project’ success of outputs, with the more strategic outcomes and SDG impacts ‘post-project’.

The results provide insights for further research. The next stage of the research is to develop the Infrastructure SDG Measurement methodology (proposed in Figure 41), into a fully defined methodology that can be tested in industrial scenarios on identified projects. These case studies will include both developing and developed countries and will focus on a single asset type across the national economic infrastructure categories of either energy, waste, water, transport, or ICT. The practical application is significant since, with improved linkage of tactical delivery to strategic SDG impacts, improved investment decisions will be made, and systemic level lessons can be applied to increase the likelihood of success in achieving the SDG 2030 targets.

## Acknowledgements

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# Local Economic Development through Infrastructure Procurement: Exploring the Social Sustainability Nexus

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## **Abstract:**

South Africa remains plagued by various socio-economic challenges. Successive governments in the country have resorted to the initiation of several developmental concepts to curb these challenges within communities. Sustainable infrastructure development happens to be one of such concepts. Yet, disadvantaged communities in South Africa are consistently bereft of adequate infrastructure stock. Obviously, there is need to approach infrastructure development in these communities with a long-term social and economic development strategy to engender enduring social change. Although extant sustainable infrastructure development strategies have supported the incorporation of economic and environmental sustainability dimensions during planning, procurement and delivery phases, a near neglect of social sustainability dimensions appears to be the norm. However, scholars posit that the implementation of sustainable infrastructure delivery must involve the integration of all dimensions in manner suggestive of relevant trade-offs. However, this is not the case within the South African infrastructure delivery landscape. This study explored various socio-economic development strategies employed during the planning and procurement of infrastructure projects by Infrastructure client organizations (ICO) to ascertain the social sustainability aspects considered during the initial phases of the project lifecycle. A case study of an ICO (a Metro Municipality-MM) was understudied. Interviews were held with a purposively selected sample of interviewees. The qualitative data was analysed using thematic analysis and the quantitative data was analysed using descriptive analysis. Findings indicate minimal knowledge of aspects concerning social sustainability thereby culminating in the non-integration of such aspects during the procurement of infrastructure projects by ICOs.

***Keywords:** economic development strategies; economic growth; social sustainability; local government; sustainable infrastructure*

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## **1. Introduction**

Historically, South Africa has been confronted with the task of developing and reconstructing the infrastructure in a manner that supports social inclusiveness and cohesion. This has led to development of strategies in relation to economic transformation whilst seeking to curb the socio-economic challenges, which have stagnated the country's developmental growth. Numerous initiatives and developmental programmes have been in place since the advent of democratic governance in 1994 and government has always tried to put the society and the disadvantaged communities first in order to find solutions to the existing challenges as well as tackling issues of exclusion and economic deprivation being experienced therein (Cheru, 2001). Twenty-five years into the nation's democracy, government is still faced with

the task of bringing about the necessary development strategies to resolve the socio-economic challenges still facing South Africa due to structural and political reasons. This is despite its explication of different interventionist packages for transformation, infrastructure development inclusive.

Yet, all these development strategies must align with the Sustainable Development Goals (SDGs). Over a sixteen-year period (1972-1986), the debate over ways to link the state of the deteriorating environment and the consumption of the limited natural resources had come to the fore of global developmental discourse. This debate gave rise to the Brundtland Commission Report which is commonly referred to as having put forward a widely accepted definition of the term 'sustainable development' (Drexhage and Murphy, 2010). Dimitriou et al. (2013) further broadened the definition of the term, from the Brundtland Report's 'meeting the needs of the present generation without compromising the ability of future generations to meet their needs' to looking into what processes of development need to be prioritized and the manner in which they need to take place. Sverdrup and Rosen (1998) opine that sustainability relates to using the ecosystem's resources to the maximum without affecting or degrading the resource base, structure or function of such ecosystem. Costanza and Patten (1995) believe that the concept of sustainability could mean a system that survives or persists without depleting its resource.

The development of infrastructure remains critical to economic growth and social cohesion and security. This is particularly the case in developing countries like South Africa where there is consensus on the need to improve on the infrastructure stock and facilitate improved levels of national competitiveness. Yet, the development of infrastructure must be done in a manner that depicts compliance to the sustainable development ethos. A cursory look at the South African infrastructure procurement landscape indicates an overt concentration of extant policies on the economic and environmental aspects of sustainable development with minimalistic attention to the social aspects. As a result, the considerable infrastructure investments made in the country seem to have failed to stem the socio-economic challenges being faced by a majority of the previously disadvantaged population. This happenstance has been attributed to the non-integration of all aspects of sustainable development in an integrated manner. This study seeks to explore the attitude of Infrastructure client organizations (ICO) towards the operationalization of social sustainability aspects of these local economic development strategies using a Metro Municipality case study exemplar in South Africa's Free State Province.

The rest of the paper is structured as follows: a review of relevant literature, a justification of the research methodology deployed in the study, the presentation and discussion of the study's findings and, a conclusion section.

## **2. A Review of Relevant Literature**

### *2.1. Sustainable Development*

Human activities affect the environment in a negative way and therefore a discussion on environment arose during the World Commission of Environment and Development (WCED)

where environment degradation was discussed. The emergence of the concept of sustainable development came about from this commission's deliberations (WCED, 1987).

With the burgeoning incidence of environmental deterioration and degradation being experienced globally, the protection of the environment has become a critical issue. The “nexus thinking” which was conceived by World Economic Forum (Bizikova et al., 2013), tried to solve the management of poor resources by linking the use of resources for provision of basic and universal rights to food and energy security. Hoff (2011) explores other versions where water resources is regarded as a central component with the water-energy-food nexus approaches whilst Ringler et al. (2013) presented the nexus framework of land-water-energy linkages.

These frameworks outline the importance of the ecosystem function together with the service to human well-being producing a strong links between the ecosystem and livelihoods. Records have it that developed and developing countries contribute to environmental degradation. For instance, countries like China and United States of America (USA) contributes about 20, 2% and 19.1% respectively to the world's environmental degradation World Economic Forum (WEF, 2011). The same applies to developing countries. High income countries make up only one-sixth of the world population but have a huge impact on polluting the atmosphere with greenhouse gas (GHG) emissions (Iea, 2010).

## *2.2 Local Economic Development strategies through procurement*

The construction industry contributes significantly to the development of any country. It accounts for the economic development and growth of countries as it contributes to the employment of the citizens. Local Economic Development (LED) refers to the programmes that are initiated at a local level, targeting the communities that are going to be affected by the project. The project can be a community-based project that is identified by the Municipality in the IDP and can be in partnership with the community as well as other stakeholders. These types of projects are used to address the socio-economic challenges of that particular community. Bartik (2003) defines LED as a state when the local economy has reached a level where it can create programs to boost itself creating a wealth for its community. LED is regarded as a development strategy, whereby place-based economic development is embedded (Barca et al., 2012). Trah (2004) broadens the definition of LED by not only considering the growth of the local economy but also competing and creating more jobs with the locally available resources.

LED is regarded as a “partnership” concept and therefore all the stakeholders should be active in the delivery of the identified infrastructure project. Sibanda (2013) explains that the Constitution of South Africa obliges the municipalities to engage and promote economic development of local communities; the White Paper of local government supports the local government, which is committed to working with citizens for sustainable solutions to improve their quality of life and meet the triple bottom line. LED is backed by legislation and policies and is a statutory requirement of the local authorities, which is stated under the Local Government Municipal Systems Act of 2000.



The LED strategies are outlined by the municipality by doing an analysis of the existing situation, looking at the growth opportunities, projects that needs to be prioritized and deciding on the best strategies to achieve their goals. Two of the LED strategies that are related to this study that a municipality can identify with include:

- Development of the infrastructure, providing better living conditions and creating better economic growth
- The procurement policies and guidelines should allow small contractors and emerging businesses to provide services where they can , and if they are not graded for the work, a partnership can be sought out with the big contractors to form a joint venture to provide services (Franz-Balsen and Heinrichs, 2007, IDP, 2018/2019).

Most of the LED projects are geared towards economic growth and empowerment and this can be achieved through various programmes such as, provision of hard and soft infrastructure, poverty reduction and equity (World Bank, 2002). The goal of sustainability is to minimise the ecological footprints as well as humanity's environmental impact on the planet (Nwokoro and Onukwube, 2015). LED projects are procured by knowing the economic situation analysis of the municipality and focuses on promotion of small medium enterprise and poverty alleviation through infrastructure projects.

Public Procurement has been used a policy tool in South Africa. Prior to 1994, procurement was favouring only large and established construction companies and made it difficult for small emerging contractors to enter the markets. Only after the democracy, public procurement was recognised as a tool to solve past discriminatory policies and practices (Bolton, 2006). Principles of good governance and preferential system were introduced to address past socio-economic objectives (Ambe, 2009). Despite this introduction of strategic tools, South Africa is still facing some challenges in the application of public procurement practices (Ambe, 2016). In order for the public sector to meet the SDG's, there has to be a coherence with sustainable practices in procurement. Traditionally, procurement was focused more on value for money (VfM) without adequate consideration for sustainable development principles.

The processes within sustainable procurement involve integration of all three sustainable dimensions throughout the delivery of the project. It is noted that sustainable infrastructure also involves processes during the procurement of the project, where sustainable dimensions, social, economic and environment are incorporated. Abdul Rashid et al. (2006) described procurement as a strategy for clients to use to obtain or acquire construction products. These procurement strategies are described as organised methods, processes and procedures that need to be followed throughout the project delivery.

### *2.3.Sustainable Procurement of LED Projects*

Sustainability and sustainable development principles have increasingly become important concepts related towards the development of sustainable infrastructure. Its triple bottom line principles being economic, environment and social dimensions (Presley and Meade 2010). The development of sustainable infrastructure refers to the processes included in the project delivery should be in such a way as to have minimal impact on the environment, contributes to the

economy as well as consider the social aspects towards the society. This means that there are benefits associated with consideration of the sustainability aspects during the project life cycle.

Studies have shown that there are considerable benefits associated with incorporating these sustainability aspects during various phases of the project delivery lifecycle. It has also been noted that amongst the principles of the triple bottom line, economic and environment sustainability are considered during the procurement of the infrastructure project but only little of social sustainability is considered. During the planning phase, feasibility studies are conducted to test the impact of infrastructure project on the environment as well as on the economy. The social impact analysis is not usually conducted but the procurement policies, e.g. Preferential Procurement Policy Framework Act, No. 5 of 2000 (PPPFA), Broad-Based Black Economic Empowerment (B-BBEE) are the ones that considers social sustainability.

During the procurement of the sustainable infrastructure, the ICO has to make sure that public spending is targeted towards optimization of value for money (VfM) for the end users. Not only VfM serve as an option to look at during the procurement but it is also important to follow the guidelines and regulations for procuring sustainably (Perera et al., 2018). Treasury (2012) outlines the proposed essential projects according to the Spatial Development Framework (SDF) as well as the Integrated Development Plan (IDP), and these special documents are used in local municipalities and provincial departments in the South African government. In addition to that, it highlights the strategically planned prioritized projects from the national level cascading to provincial and local entities. In South African government, particularly the Supply Chain Management (SCM) section of Infrastructure Client Organizations (ICO), there are specific public procurement guidelines that must be adhered to for every tender that is awarded. Kaufman et al., (2012) further attest to the notion that the evaluation team's decision-making is influenced by their experience in the procurement process of the tender award and the pre-set procurement guidelines that are set through extant policies.

#### *2.4.Socio-economic development strategies: Integrating social sustainability aspects*

As part of any infrastructure development project, there are feasibility studies conducted to see how they affect the environment and the economy, but little is said concerning the social impact.

Also blamed, is the low level of awareness of the benefits accruable from an integration of social sustainability aspects during project delivery in the construction industry. This factor has culminated in the unclear nature of the social sustainability incorporation process within the realm of infrastructure procurement and delivery (Boström, 2012). (Kleindorfer et al., 2005) also demonstrate this fixation of extant research carried out within the supply chain knowledge domain on the environmental sustainability aspects whilst largely ignoring the social sustainability aspects. The World Bank is doing its part by working towards social sustainability, by initiating social protection programs that help cushion the 'severe' impact of income shocks and unemployment. This will build on resilient social protection systems (Kuriakose et al., 2013).

Robert et al. (2005) acknowledges that, there have been efforts to define sustainability with narrow definitions and failing to point its indicators, which differ greatly amongst the three sustainability dimensions, whereas Littig and Griessler (2005) confirms the three-pillar model of sustainability and emphasise on the relationship among three principles. There are indicators that are derived from; global policies, government principles, regulations and guidelines from treasury department according to the level of importance or prioritization of the kind of project being procured. These indicators can be core and additional too depending on the emphasis on social sustainability of each infrastructure client office.

Burdge (2004b) reiterates the need to focus on the impact of considering social sustainability aspects such as the end users, where they live and how they engage in their day-to-day lives. It is important to note the benefits of integrating what is considered as socially sustainable aspects across the project life cycle and to monitor the effect of the integration thereafter. For instance, the use of targeted procurement to increase the participation of hitherto underrepresented communities in the construction industry is a case in point. Therefore, sustainable infrastructure project delivery implies the optimal integration of sustainability ethos into these phases in a manner that will yield to more sustainable outcomes.

According to an integrated plan of a municipality (IDP, 2018/2019), it shows that there are multiple opportunities for any social dimension aspect to be incorporated during the pre-construction phase. These social aspects include training and skills development for the users of the project, consideration of health and safety on site for the construction workers, and to bridge the socio-economic challenges faced by the beneficiaries of the infrastructure project. The document further explains that projects to be procured are identified either by selection from the list of government prioritised projects or according to the needs analysis of the communities in that local area. A proper consultation with the community before the construction of the infrastructure project, which Valdes-Vasquez and Klotz (2012) considered as one of the social sustainability aspects, is formally conducted. Through this community engagement, the stakeholders can be able to predict the social impact of the project on the community.

Burdge (2004a) suggest that these consultations are essential, as one can be able to monitor and measure the impact of these infrastructure projects on all the sustainable dimensions. A process of how community can participate and be engaged during the construction of the project is also outlined in the IDP. Community participation and engagement forms an integral part of the social sustainability aspects such that the community becomes fully the stakeholders of the projects. Focusing on sustainability on a social level, requires an understanding of a well-attuned area specific issue (Andreas, et al., 2010). Community experts view these embedded aspects as intangible to developers but important as economic and environmental dimensions (Hammond and Peterson, 2007).

### **3. Research Methodology**

The case study research strategy was adopted. The data was collected using a mixed method. Yin (2003) further draws the attention that a case study strategy can be used to answer how and why questions and focuses on phenomena in real-life context.

The selected case study is used to address a particular issue in depth and enables the researcher to cover a large amount of ground. A case study of a Metro Municipality in the Free State was identified as a case study. Semi-structured interviews of purposively selected thirteen (13) ICO personnel were carried out fully to understand the types of development strategies considered during the initial phase of the project cycle. The participants selected were in the section of the departments where the relevant information is required. Purposive sampling is the deliberate choice of the sample of the group to be used due to their qualities the sample group has (Tongco, 2007). The case study strategy is able to facilitate the exploration of a phenomenon in its context using different data sources and the issue can be revealed and understood in multiple facets (Baxter and Jack, 2008). A qualitative data was analyzed using a thematic analysis, where data was transcribed. Identified themes were, socio-economic development strategies and sustainable infrastructure development strategies. The themed data was grouped and given back to the respondents to rank them according to how they understood the concept of sustainability and prioritize the identified social sustainability aspects.

#### **4. Presentation of Findings**

The interviews conducted were 13 (thirteen) in total and the data presented in themes. The respondents were also given questionnaires to complete based on the data they have given from the interviews. From the 13 (thirteen) interviews conducted, the findings for this case study revealed that the respondents knew about sustainability but few of them knew what it meant. The interview questions posed to the personnel were structured thematically. The first theme had questions relating to the criteria the personnel follow for labour relations, community engagement, skill training strategies and the community benefits from infrastructure development. The second themed interview questions were socially related activities to consider or incorporate during procurement of the infrastructure project and which of the aspects are mostly considered and the reasons behind their choices.

The interview questions posed to the personnel of the ICO were structured such that the interviewees would be able to elaborate on what they think sustainability is, and what they consider for the society during the planning of the infrastructure project. Although some of the personnel claimed to have knowledge of the concepts, this led to an unclear nature of the social development strategies and in particular, the social sustainability aspects (Boström, 2012). This information was ranked using a Likert scale to show the level of importance of the variables according to the themes.

#### **5. Presentation of Data**

##### *5.1. Presentation of Qualitative data*

Theme 1: Socio-economic development strategies: understanding the concept of social sustainability aspects

Contractors are monitored during the adjudication committee to check if they comply with the labour relations act. The respondents agreed that there is employment of the locals that is

considered and at times, it is compelled by the specified and labour relations act. The employment of the locals being considered as one of the benefits of the outcomes of the infrastructure project (Burdge 2004a). One technical administrator agreed that they have to advertise the information about the contract. One manager noted that it is also the ward councilor's duties to inform the community members in his respective ward about the upcoming projects during their ward meetings. Municipality advertises information about the projects on government gazette for public access.

“There are trainings and workshops that are specific for the emerging contractors, seen that there is a huge need for skills for sustenance and be able to work on other projects and not just one project in a specific area”. Manager: CFO.

Most of the emerging contractors will opt to subcontract and thereby enhance their skills through the work they are sub-contracted.

“IDP is one document that outlines all projects that the municipality is intending to start during a specific financial year. It stipulates what is prioritized nationally and locally or a specific community”. Manager: Strategic Services.

## 5.2 Presentation of Quantitative data

Table 1: Key Concepts of Sustainability and Sustainable Development

Variables	N	Mean	Std. Dev.	Rank
Training workshops on sustainable project alignment with government basic needs	13	2	0	1
Practices which are aligned with sustainable development	13	2	0	1
Best practices	13	2	0	1
Equitable provision of basic needs	13	1.92	0.277	4
Community benefiting from government projects	13	1.92	0.277	4
Enforcement of sustainable practices	13	1.85	0.376	6
Capacity Development	13	1.85	0.555	6
Integration of social, economic and environment	13	1.85	0.555	6
Research and Development	13	1.77	0.599	9
Education and Training	13	1.77	0.599	9
Government regulations in line with the NDP	13	1.69	0.63	11
Working for and with the community	13	1.69	0.63	11
Protection of the environment	13	1.46	0.776	13
Global issues	13	1.46	0.776	13
Health and Safety management	13	1.38	0.87	15
Effective supply chain management	13	1.38	0.87	15
Efficient use of resources	13	1.38	0.87	15
Stability of the communities	13	1.38	0.87	15
Conservation and Enhancement of the natural resources	13	1.38	0.768	15
Development and preservation of natural capital	13	1.31	0.751	20
Enforcement of Policies	13	1.31	0.63	20
Regulations and Policies	13	1.31	0.63	20
Resource and waste management	13	1.31	0.63	20

Rights of employees	13	1.23	0.832	24
Environmental Issues	13	1.15	0.801	25
Human Rights	13	1.15	0.801	25
Influence of local communities	13	1.08	0.954	27
Conservation of species diversity	13	1	0.816	28
Information Disclosure	13	0.77	0.927	29
Business Practices	13	0.77	0.927	29

#### Summary of key concepts of sustainability that have been ranked the most

The result reveals that ‘Training workshops on sustainable project alignment’, ‘Practices which are aligned with sustainable development’ and ‘sustainability and sustainable development mean best practices’ were ranked first with a mean score of 2.000 and (Geissdoerfer et al.) = 0.000. ‘Equitable provision of basic needs’ and ‘Community benefiting from government projects’ were both ranked fourth with a mean score of 1.9 and (Geissdoerfer et al.) = 0.277 each. This confirms the respondents’ perception of sustainability and the processes of attaining these above-mentioned aspects as prioritized by being ranked high compared to other variables.

For the first theme, the respondents reveal that although they understand the concepts of sustainability, which mostly involves training and workshops, sustainable best practices and consideration of basic needs, they further confirmed this on the questionnaires by how they prioritized these variables for their local development.

### 5.3 Presentation of Qualitative data

#### Theme 2: Sustainable Infrastructure Development: Identification of aspects

The respondents understood the type of infrastructure projects they were procuring and were aware of the different project phases of the project. They confirmed that a needs assessment is done about the area where the project will be located and its benefits to the community. The needs assessment provides a clear report on how the project is going to affect the environment and the economic status. They noted that the social assessment is rarely prepared as the policies that are functional in terms of consideration of social sustainability during the procurement of the infrastructure project already considers the disadvantaged individuals. Although the personnel are not aware because of lack of knowledge of sustainability, there are few aspects that are considered during the planning of the infrastructure projects and which are

- Employment of skilled labour for the infrastructure project
- Training of the unskilled for future employment
- Reducing poverty
- Health and safety
- Women empowerment
- Informing the community of the project and possible job opportunities

Burdge (2004a) reiterates that from the level of impact, the project will have the social, environment and economic assessment by engaging the community through various modes of

communication; it is easy to know from their responses how they will benefit from the project. Community engagement is emphasized here as the community is made aware, know of what is happening within their community and how the project will benefit them, their responsiveness is most of the time positive especially if they benefit mostly from the project itself or if the project will change their economic status and quality of life (Valdes-Vasquez and Klotz, 2013).

A needs analysis conducted by the ICO during the planning phase of the project might even influence that community members be invited to be part of the design team in cases where the project is specific and according to the community needs.

“Certain projects are not always in line with what is in the IDP or spatial development framework or according to the national development plan and therefore strict measures have to be considered and there should be a motivation as to why a specific contract be considered”.  
 Technical Director

The table below shows the results of the quantitative data of what social sustainability aspects are identified in this PMM ICO and their level of ranking from the most significant aspects to the least significant aspects. It tables the variables according to the highest ranked variable to the lowest ranked variable according to their organization.

#### 5.4 Presentation of Quantitative data

Table 2: Social Sustainability Aspects Identified

Variables	N	Mean	Std. Deviation	Rank
Community Involvement in the project	13	5	0	1
Empowerment and Participation	13	4.92	0.277	2
Employment of the affected stakeholders	13	4.92	0.277	2
Community Engagement	13	4.92	0.277	2
Training and skills development	13	4.85	0.376	5
Reducing Poverty	13	4.46	0.66	6
Working Conditions	13	4.31	0.63	7
Gender Balance	13	4.23	0.599	8
Safety through design	13	4.15	0.555	9
Security	13	4.08	0.76	10
Corporate Social Responsibility	13	4.08	0.954	10
Health care	13	4	0.707	12
Social design	13	4	0.577	12
Social equality and justice	13	4	0.408	12
Social Performance	13	3.85	0.899	15
Pride and sense of belonging	13	3.85	0.801	15
Human Rights	13	3.69	0.855	17

Summary of social sustainability aspects identified that have been ranked the most

The results reveal that ‘Community Involvement in the project’ ranked first with a mean score of 5.00 and (Geissdoerfer et al.) = 0.000. ‘Empowerment and Participation’, ‘Employment

of the affected stakeholders' and 'Community Engagement' were ranked second with a mean score of 4.92 and (Geissdoerfer et al.) = 0.277. 'Training and skills development' ranked fifth with a mean score of 4.85 and (Geissdoerfer et al.) = 0.376. These results reveal that the interviews conducted confirmed aspects that can be identified during the procurement phase and the respondents were able to rank them according to what they identify first when procuring for infrastructure projects.

The data presented shows that there are aspects that are considered during the procurement of infrastructure projects and consideration of the community affected by the infrastructure projects is given utmost high importance. This is seen through empowering the community members by giving them first preference when it comes to employment. Training and upskilling the local members contribute more to enhancing skills and exposing them to different job opportunities besides the one provided by the local projects.

## **6. Conclusion**

The study explored the different development strategies that are employed during the procurement of infrastructure projects. The literature gave a background on the benefits of being aware and understanding what the concept of sustainability is. It also introduced the triple bottom line where all three dimensions social, environmental and economic sustainability should be in balance with each other to attain a sustainable infrastructure project. The different meanings were given by the respondents about how they relate and their experiences about the projects they have done previously. Their experiences and their relationship towards the integration of social sustainability aspects are mostly based on the traditional procurement processes.

Information from the ICO revealed that personnel knew about the concept of sustainability but because of lack of awareness and in-depth knowledge of the benefits of the concepts, the integration of social sustainability aspects during the initial phase became a problem for the personnel. Without proper training and regulations about the integration of sustainability within the supply chain management, the personnel will not have a morale to implement sustainability aspects. Whilst there are few steps taken by government towards developing strategies towards sustainable procurement, there is still a high demand of development of technical specifications by expertise to design with implementing sustainability and processes thereof, which will be applied during the construction phase. The suppliers should be developed to be able to respond to sustainable public projects when advertised.

The data from the interviews also revealed that the SCM policies that are implemented during procurement of the infrastructure project considered some of the social sustainability aspects, but due to knowledge of what sustainability is or identification of its aspects, it is difficult for the integration of these aspects. Government can find experts, leaders and champions in building and developing strategies for sustainable procurement. Sharing best practices among the local municipalities can enhance the ICOs performance.



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# A Sustainability Model of 217 Agents for Commercial Buildings

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## Abstract

In this paper, we conceptualize and use the triple bottom line (TBL) approach and empirically assess sustainability, which comprises three distinct dimensions (i.e., three separate dimensions into one construct). We assess the validity of a three-dimensional model; if these dimensions are distinct dimensions; and to what extent these affect sustainability performance and sustainability consequences. A targeted group of commercial building agents (N=217) was selected to assess this behavioral model. In applied behavioral sciences, which includes sustainability, we often consider agents as subjects of knowledge. Building agents are also key recipients who address building requirements during construction procurement processes. Their perception on sustainability is therefore an important assumption to consider for any building framework. The paper aims at developing a framework based on a testable model that extends existing research in at least two important ways: It provides a test of the reliability and validity of a higher abstraction of sustainability by proposing a second order model; and it develops and distinguishes between sustainable goals, sustainable performance, and sustainability consequences. The entire framework thus provides important topics for future research in the extant literature. The specific results show that sustainability affects both sustainable performance and sustainability consequences. These findings are not aiming for conceptual confusion but to clarify and distinguish between the loops of sustainability work and its effects on management. As many practitioners work with unbalanced models, the findings have important theoretical and practical implications.

*Keywords: sustainability; commercial buildings; structural equation modelling*

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## 1. Introduction

A goal refers to activities you target (likelihood), while behavior is a determined activity that you subsequently do (I do sales Y/N). We suggest that, just as innovation is the outcome of innovativeness (Nybakk, Crespell, Hansen, & Lunnan, 2009), the sustainability process affects sustainability performance (Garay, Font, & Pereira-Moliner, 2017) and subsequent behaviors are sustainability consequences (Smith, 2007). Sustainability is defined as the ultimate means of what you ought or plan to do and is often reflected by an individual's sustainable goals. Conceptually, we recognize sustainability by its key properties of ecological, social, and economic goals (Gupta & Vegelin, 2016; Lamberton, 2000) and, if possible, convert those practices into sustainable behavior (Murillo-Luna, Garcés-Ayerbe, & Rivera-Torres, 2011). Sustainability thus covers conversion of sustainable goals and its effects (Büyükközkán & Karabulut, 2018) and transformation into sustainability consequences (Vallance, Perkins, & Dixon, 2011). Such conversion is vital to an applied literature like sustainability. Theoretically,

sustainability involves the ability to match goals effectively and efficiently with operations, and simultaneously guarantee resources for future generations (Odufuwa, Fransen, Bongwa, & Gianoli, 2009). While other resource allocation models isolate and focus on current activities to improve productivity and efficiency, sustainability becomes a key concern of those activities for future sustainable activities. Such a goal–consequence mindset is therefore complex and requires intuitive goals, practices, and policies.

This area is important in many ways. When planning new areas, it is important to consider these dimensions so that function and form match the surrounding area (Robin & Poon, 2009). While some pay attention only to environmental issues, others tend to balance social and economic sustainability to some extent. There is thus variation if one dimension dominates the others or there is an equivalent priority on each dimension. The latter not only affects the way we maintain buildings but also the way we plan future construction projects. Focusing on the consequences of sustainability is also important as it may more strongly direct control toward practical hands on strategies for pollution prevention, shared product responsibilities, life-cycle analysis, and concerns for local and global value standards.

The entire literature on sustainability has grown in many ways. Sustainability involves a rich conceptual variety in how it can be understood (Vallance et al., 2011). Its academic impact and applicability have increased over the years (Ma, Harstvedt, Dunaway, Bian, & Jaradat, 2018). There is also a consensus on the multi-dimensional—ecological, social, and economic—practice of sustainability (Clune & Lockrey, 2014). While the differences can increase understanding of the concept, there is work to be done to standardize and bring together conceptual nuances. While some argue that ecological goals are principal to social and economic goals, others claim that ecological goals need to be intertwined with social and economic goals (Winkler, 2010). The latter can only be achieved by proposing conceptual hierarchies and schemes addressing actions as a way to reach such plans.

The use of hierarchical conceptual maps of what comes first and where goals may lead to consequences is positioned in the performance measurement systems literature (Searcy, 2011). Within this domain, researchers started to benchmark sustainability performance toward other organizations (Garay et al., 2017; Morioka & de Carvalho, 2016). The conceptual critique is that measures may lose congruence by using different means to measure the same thing (Vallance et al., 2011). Researchers are therefore urged to address sustainability performance with sustainability indicators (Büyükožkan & Karabulut, 2018; Morioka & de Carvalho, 2016). The problem remains, however, that these indicators are not standardized to their full extent. The literature has rapidly expanded, and the concept is referred to as sustainability performance (Garay et al., 2017), corporate sustainability performance (Büyükožkan & Karabulut, 2018) and more narrow studies focusing on environmental performance (De Burgos-Jiménez, Cano-Guillén, & Céspedes-Lorente, 2002).

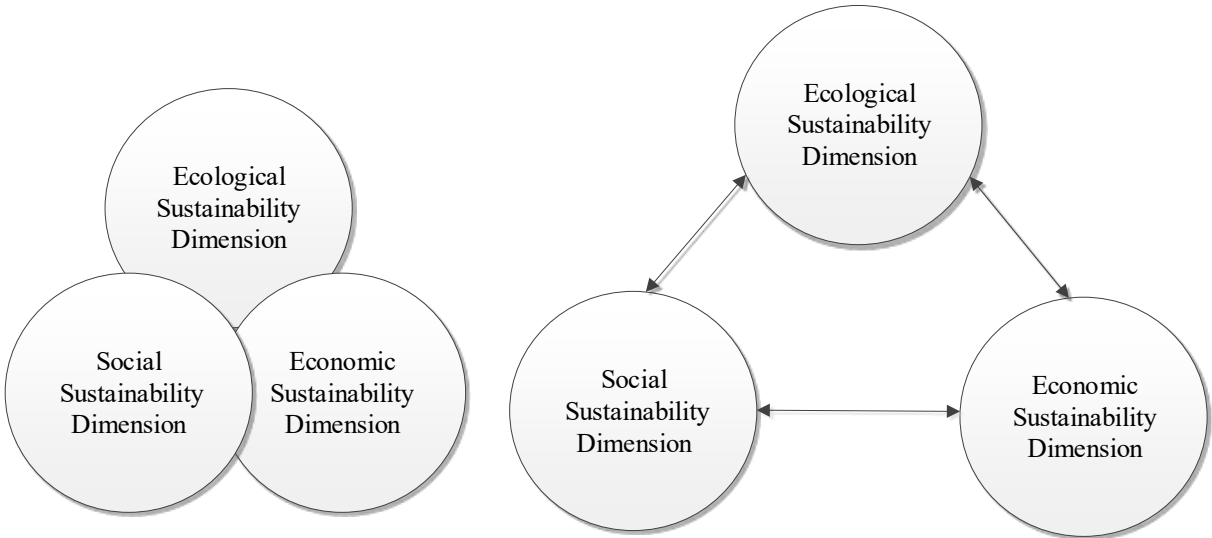
Despite a conceptual incongruence, the bottom-line of sustainability ultimately addresses ways to reach awareness and further stress specific behavior in a certain direction (Zsóka, 2008). Conceptual vagueness also inspires new domains for sustainability. More prominent

analytical empirical lenses with more solid behavioral principles on sustainability issues may inspire improved conceptual and theoretical diagnostics with different analytical approaches to solve sustainability issues (Morioka & de Carvalho, 2016; Hirsh, Costello, & Fuqua, 2015; Vallance et al., 2011).

While the widespread impact of sustainability tends to inspire new studies, there is a limited effort made to integrate and offer conceptual theoretical standards of the construct. This paper is therefore an effort to bring together properties of what we refer to as sustainability into one construct. We not only conceptualize the same thing differently but also hierarchically suggest a process by which these sequences take place. We further suggest that sustainability may affect sustainable performance and sustainability consequences. The paper suggests an overarching second order construct to bring together ecological, social, and economic dimensions into one single construct that is sustainability and test its effect on sustainability performance and sustainability consequences. While the literature exhaustively considers these as three dimensions, no one to our knowledge has tested the validity (convergent validity) of such a second order model. By testing these dimensions, the paper also suggests a unique index of behavior referred to as sustainability consequences by summing key activities of key subjective knowledge agents representing commercial buildings. The paper has important conceptual implications for practice and suggests means to develop practices by separating goals from outcomes and behavior.

**2. Theoretical framework of sustainability**

The subsequent sustainability model hinges upon two assumptions: the TBL approach proposes that sustainability can be formed weakly or strongly (Neumayer, 2003); and the way you approach sustainability will result in the approach becoming political (Kern & Smith, 2008) and ideological (Robin & Poon, 2009). While the past 20 years have veered toward a weaker independent approach with various attention on the different dimensions of sustainability, the beginning era and more recent trends focus on a stronger non-interchangeable approach.



**Figure 1a:**  
Strong non- interchangeable sustainability approach

**Figure 1b:**  
Weak interchangeable sustainability approach

The strong approach has long been criticized, mainly because the dimensions are not interchangeable (Neumayer, 2003). This means that a poor focus on environmental standards would also hamper wellness, wellbeing, and financial and economic conditions (Upward & Jones, 2016). This results in a situation of strong balanced and integrated dimensions (see Figure 1a). Under the strong non-interchangeable approach, dimensions are paid the same amount of attention; they are equally important and balanced by conceptual distance. The weak sustainability approach (see Figure 1b) suggests that the dimensions are interchangeable, which means that the dimensions may not have need to be balanced and weak environmental standards are not necessarily bad for social and economic conditions (Ahi, Searcy, & Jaber, 2018). The implication is thus that you can support social and economic standards by substituting these fully by environmental standards. This means the size of each dimension could differ and the relationship indicated by arrow could differ in strength and socio/psychological distance. This would indicate that the dimensions are independent, and strategies to reach outcomes should be pursued independently (see Figure 1b).

One way to frame a theory (Kuhn, 1970) is to list activities with corresponding assumptions and define their association to the idea. Such assumptions propose a language with explicit and implicit properties assigned for an applied situation. An overview of some assumptions is presented below.

First, sustainability is understood as an applied science (Popa, Guillermin, & Dedeurwaerdere, 2015). This means the degree of sustainability determines the gap between behavioral practice and policies (Crilly, Hansen, & Zollo, 2016). Thus, sustainable goals and sustainable behavior (or lack of it) have consequences on sustainability (Vallance et al., 2011). The more specific and thoughtful the goals tied to specific behavior, the more likely individuals will behave accordingly. Likewise, diffuse goals will make it more difficult for individuals to reach desired outcomes. The more thoughtful goals are, the more aware individuals will be about priority of those goals, and the more likely feedback can be tailor-made, desired activities rewarded, and other controls be coordinated to achieve sustainability.

Second, sustainability is conceptually a framework that responds to evolution (process) of behavioral consequences (social, economic, and ecological activities) (Petrișor & Petrișor, 2014). Behavior is thus an assumption, which can be determined by assigned properties (Vallance et al., 2011). Third, sustainable behavior can furthermore reflect a number of necessary conditions (Bithas, 2011) to form something recognized as sustainability or sustainable behavioral properties (Martin, 2015). Such sustainable behavior is conditioned by sustainable goals targeted toward an actual behavior. While goal-directed behavior typically uses the lens of behavioral controls (see, e.g., Ajzen, 2002), another applicable approach for sustainability focuses on deviations of sustainable behavior (Loock, Staake, & Thiesse, 2013) also referred to as decoupling (Lidskog & Elander, 2012). Fourth, goal direction or absence of direction is thus another assumption of sustainability. Sustainability can therefore be explained by the gaps between policy, implementation, and practice (Crilly, Hansen, & Zollo, 2016).

## 2.1 Research hypothesis

Sustainability consequences are the effect of sustainable behavior with concrete action plans (Morioka & de Carvalho, 2016) wherein agents of sustainability knowledge increase awareness and further performance (Martinez-Martinez, Cegarra-Navarro, Garcia-Perez, & Wensley, 2019). Sustainability process can therefore be the consequence of sustainable goals (Hirsh et al., 2015). Such consequences can be short or long term. A number of studies treated sustainable consequences as sustainable performance (Francis & Huggett, 2018; Garay et al., 2017).

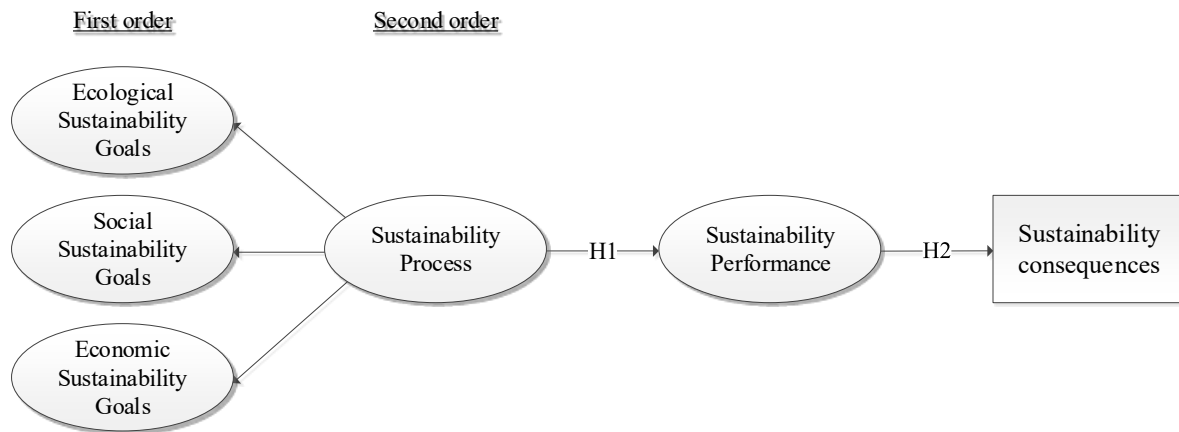


Figure 2:

Proposed Strong Theoretical Structural Sustainability Model

## 3. Research design

In reporting results, we follow Agan, Acar, & Borodin (2013), using a similar approach to their study.

### 3.1 Data collection

This paper is based on a cross-sectional study using survey data. Students were instructed to collect the data as part of their term project. Data collection was targeted toward managerial agents for commercial buildings, thus representing subjective informed knowledge agents. A total of 217 full responses were returned from these key commercial building agents, with 60% of the agents operating in a private organization (Table 1). The majority of respondents were males (61%); 81% of respondents were older than 40 years; 56% have more than 5 years of experience in the organization; and 29% were either a CEO, controller, or in production, whereas the rest of the group defined their work role as operating in areas such as IT, communication, and administration. Most of the organizations (77%) had a formal public annual sustainability practice (reporting). Most of the key informants were formally assigned to take an active part in the report (92%), had their own interest in the report (83%), supported their decisions (72%), and/or were important for informational purposes (80%). The targeted group was thus assigned to statistically represent informed sustainability key knowledge agents.

Table 1: Respondent Profile (N=217).

Organization	N	%
Organization		
Public organization	87	40%
Private organization	130	60%
Gender		
Females	85	39%
Males	132	61%
Age		
Age < 40	41	19%
Age 40 ≤ 50	93	43%
Age > 50	83	38%
Annual susatainable report		
Yes	167	77%
No	50	23%
Years in the organization		
Years < 5	97	44%
Years > 5	121	56%
Work role		
CEO	28	13%
Controller	14	6%
Production	22	10%
Other	153	71%
Expected to actively work with CSR reporting (practice)		
Yes	199	92%
No	18	8%
Own interest in CSR reporting (practice)		
Yes	180	83%
No	37	17%
CSR report important for me to reach decisions		
Yes	157	72%
No	60	28%
CSR report important for informational purposes		
Yes	173	80%
No	44	20%

### 3.2 Measurements and unidimensionality

A structured questionnaire with four established multi-item scales was used. Since these scales were developed in English, back-translation was used to ensure equivalence of items. Two different 7-point Likert scales were designed to reflect sustainability process (ecological, social, and economic) dimension and sustainability performance. Since we were interested in goal practice and decoupling, we designed the scale with anchors from a degree that ranges from operating less than what was expressed in the goals (-3) to more than expressed in the goals (+3). A Likert scale for innovation performance was also used anchoring the relative performance to competitors by assessing -3 worse than competitors to +3=better than competitors. Finally, a composite score of sustainability consequences that varies between 0–16 was determined by assessing sustainability activities (behavior) that these subjective agents do (yes/no) and summing all “yes” responses to generate a score.

Since we introduced new anchors and used fewer items in the scale than in previously used scales, we undertook an assessment of convergent and discriminant validity by following similar procedure to Agan et al. (2013). Exploratory factor analysis (Table 2) also provided



insights on potential so-called cross loading issues and proof of common method bias (Podsakoff, MacKenzie, Podsakoff, & Lee, 2003).

Table 2: Exploratory Factor Analysis (N=217)

	Ecol
Ecological goals process	
Seeking alternative ways for energy efficiency (heat, water, electricity).	0.80
Choosing suppliers with regard to sustainability.	0.83
Choosing environmentally friendly options when purchasing.	0.79
Social goals process	
Match job ads to our social standards	0.88
Match communication materials (external, internal) with our social standards.	0.79
Work actively with gender equality within the organization.	0.73
Economic goals process	
Follow society's expectations regarding taxes.	0.89
Follow society's expectations regarding pensions.	0.92
Follow society's expectations regarding minimum salaries	0.85
Sustainability performance	
Offer environmentally adapted products / services.	0.86
Select suppliers for durability.	0.84
Meeting customer expectations with sustainable ends (i.e., products).	0.87
<u>Extraction Method:</u> Principal Component Analysis. <u>Rotation Method:</u> Varimax Kaiser Normalization (Rotation converged in 6 iterations). <u>Eigenvalue:</u> 1.12. <u>Total variance explained:</u> 79%.	

*Ecological goals sustainability dimension:* Items were deduced from Garay et al. (2017). We used three items on ecological sustainability: (1) Constantly seeking alternative ways for energy efficiency (heat, water, electricity); (2) choosing suppliers with regard to sustainability; and (3) choosing environmentally friendly options when purchasing. The scale received satisfying reliability exceeding the recommended .70 cut-off (Cronbach's alpha=.80), and convergent validity was satisfying as loadings were well-balanced and substantial ranging between .79–.83.

*Social goals sustainability dimension:* Items were deduced again from Garay et al. (2017). We used three items on ecological sustainability: (1) Match job advertisements to our social standards; (2) match communication materials (external and internal) with our social standards; and (3) work actively with gender equality within the organization. The scale received satisfying reliability exceeding the recommended .70 cut-off (Cronbach's alpha=.88), and convergent validity was satisfying as loadings were well-balanced and substantial ranging between .73–.88.

*Economic goals sustainability dimension:* Items were deduced again from Garay et al. (2017). We used three items on ecological sustainability: (1) Follow society's expectations regarding taxes; (2) follow society's expectations regarding pensions; and (3) follow society's expectations regarding minimum salaries. The scale received satisfying reliability exceeding the recommended .70 cut-off (Cronbach's alpha=.92), and convergent validity was satisfying as loadings were well-balanced and substantial ranging between .85–.92.

*Sustainability performance:* Items were deduced again from Garay et al. (2017). We used three dimensions on sustainability performance: (1) Offer environmentally adapted products/services; (2) select suppliers for durability; and (3) meeting customer expectations

with sustainable ends. The scale received satisfying reliability exceeding the recommended .70 cut-off (Cronbach's alpha=.87), and convergent validity was satisfying as loadings were well-balanced and substantial ranging between .84-.87.

#### 4. Data analysis and results

Data analysis followed a two-step approach (Anderson & Gerbing, 1988). A two-step approach is a standard procedure for structural equation modeling (SEM). The approach means that measurements are accurate and distinct from each other so that validity issues do not bias the structural model. The first step is referred to as Confirmatory Factor Analysis (CFA) and the second step is the test of hypothesis and structural model.

##### 4.1 Confirmatory Factor Analysis (CFA)

Following guidelines for assessing model fit from Bagozzi and Yi (2012), the CFA test provided strong support for the underlying specified second order factor structure. As Chi square ( $\chi^2$ ) is known as sensitive to larger sample size ( $N > 100$ ), it also tends to become significant ( $p$ -value  $< 0.05$ ) and thus tends to not reject differences between observed data and the specified model the recommendation is to follow non-sensitive goodness-of-fit indices (Bagozzi & Yi, 2012). Other goodness-of-fit indices include Standardized Root Mean Residual (RMR) and Root Mean Square Error of Approximation (RMSEA), expected to be lower than .08 (Bentler, 1990), and Comparative Fit Index (CFI), recommended to exceed .90 (Hair, Black, Babin, & Anderson, 2010). Table 3 provides strong evidence that our specified model is supported by data (Table 3: CFI = .96, RMSEA = .07, SRMR = .06, and  $\chi^2 = 129.25$  [df = 60;  $p \leq .000$ ,  $\chi^2/df=2.15$ ]).

Table 3 provides support for convergent validity. Following Hair et al. (2010) all measures exceed recommended loadings above .60, composite reliability greater than .60, and average variance extracted greater than .50.

Table 3: Full measurement model (CFA)

Question and construct	Standardized Loadings	Composite Reliability (CR)	Average Variance Extracted (AVE)
Sustainability		.60	.50
Ecological sustainable goals	.73		
Social sustainable goals	.74		
Economic sustainable goals	.64		
Ecological sustainability goals		.72	.59
Ecological 1	.62		
Ecological 2	.84		
Ecological 3	.83		
Social sustainability goals		.74	.61
Social 1	.74		
Social 2	.79		
Social 3	.82		
Economic sustainability goals		.89	.79
Economic 1	.86		
Economic 2	.95		
Economic 3	.85		
Sustainability performance		.70	.82
Sustainability performance 1	.85		

Sustainability performance 2	.83
Sustainability performance 3	.83
Goodness-of-fit statistics:	
CFI = .96, RMSEA = .07, SRMR =.06, and $\chi^2 = 129.25$ [df = 60; $p \leq .000$ , $\chi^2/df=2.15$ ].	

Figures 3 and 4 provide evidence of strong (second order) versus weak (first order) sustainability modeling. Our evidence supports a strong sustainability model as Chi square is greater and much more sustainability performance can be explained.

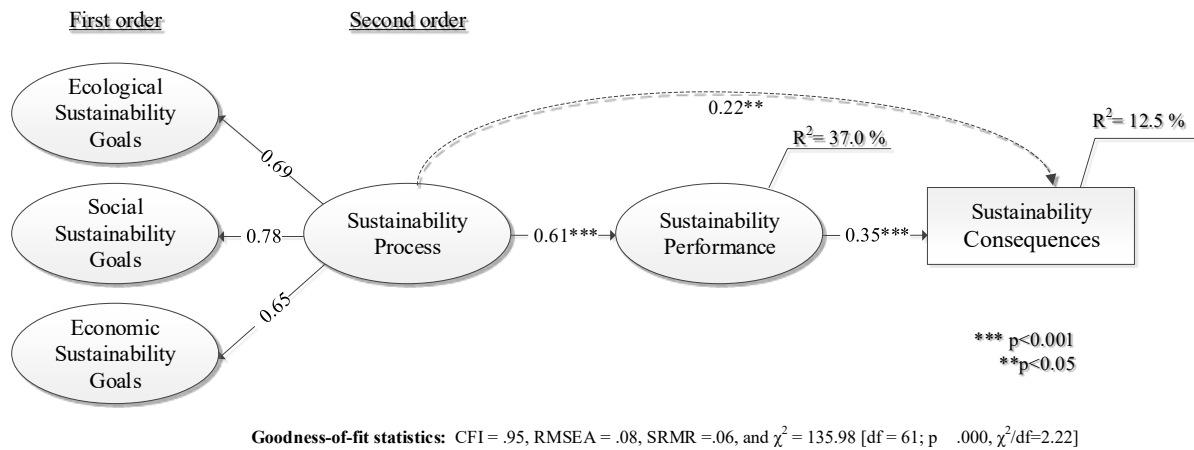


Figure 3: Results Strong Theoretical Structural Sustainability Model

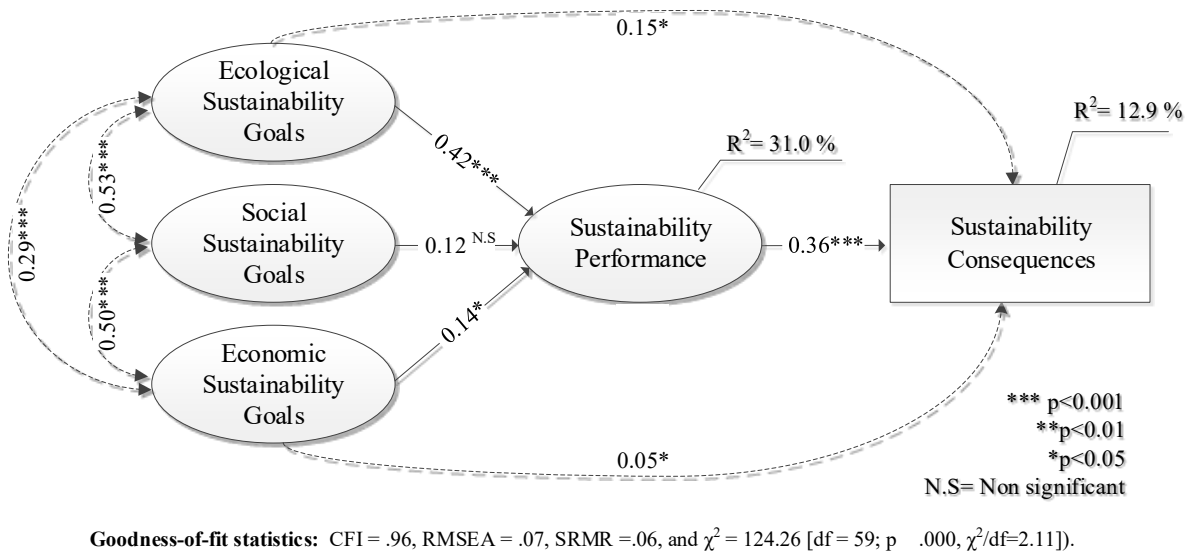


Figure 4: Results Weak Theoretical Structural Sustainability Model

#### 4.2 Structural model

Figure 3 provides an overview of the results. First, we find that the specified model is supported by the data (Goodness of fit: CFI = .95, RMSEA = .08, SRMR = .06, and  $\chi^2 = 135.98$  [df = 61;  $p \leq .000$ ,  $\chi^2/df=2.22$ ]). Furthermore, the results explain from 12.5% to 37% of the proposed dependent variables.

Turning to individual hypotheses, we expected that sustainability process affects sustainability performance (H1) which was also supported substantially by a strong beta ( $\beta = .61$ ) and statistically significant ( $p < .001$ ). Secondly, we expected sustainability performance to have a relationship on sustainability consequences (H2). Our second hypothesis was supported strongly ( $\beta = .61$ ) and was strongly significant ( $p < 0.001$ ). Our structural model also allowed us to test indirect effect, which proved that sustainability performance strengthens the effect of sustainability on sustainability consequences.

## **5. Discussion and implications**

Drawing on responses of Swedish subjective knowledge agents who operate in commercial buildings concerning their perceptions of sustainable goals, performance, and behavioral consequences, this paper confirms that sustainable behavior cannot be developed in isolation but is dependent on meaningful goals. Given the rather specified sample that also addresses requirements for procurement and planning, we may also find this significant for the construction industry. Their perception and the way they allow sustainability to form their mindset may also have effects on setting up construction projects and maintenance of such projects.

This paper theorized a proposed second order model of sustainability (i.e., three separate dimensions) and verified that these dimensions could operationalize as such. While previous literature claims and identifies such three-dimensional structures (e.g., Gupta & Vegelin, 2016; Lamberton, 2000), no one, to our knowledge, has tested such a model when connected to goals of sustainable behavior (Murillo-Luna et al., 2011).

The structural equation model has acceptable goodness-of-fit and verifies that sustainable goals have indirect effects on consequences referred to as sustainability consequences (Smith, 2007). As the study is based on a sufficiently large sample, the results are believed to be important. Below we discuss the theoretical contributions, the practical implications, and the limitations of the study.

### *5.1 Theoretical Contributions*

The theoretical framework of this study is rooted in a sustainable behavioral approach (Morioka & de Carvalho, 2016; Hirsh, Costello, & Fuqua, 2015; Vallance et al., 2011). While many attempts are made to isolate performance on rational objective grounds, this paper accepts the applied value of subjective agents for knowledge outcomes. The proposed model also attempts to organize sustainability in a testable way that simplifies communication throughout an applied situation. Using a behavioral approach and separating goals (sustainability process) from performance and consequences (sustainability consequences) allows future theories to organize sequences in behavioral life cycles. Each circle in the proposed model represents a loop and each arrow signifies a transformation or behavioral conversion of what is said in the paper and how the intervention takes place. Our first main theoretical contribution therefore concerns the development, test and verification of the conceptual model. The explanations of our findings are drawn from general behavioral theory (Cyert & March, 1963; Cheung et al.,

2003; Greve, 2003a; Lounsbury & Beckman, 2015; Schwab & Miner, 2008). We added to the notion that the sequences are interdependent and distinct from each other.

## 5.2 Practical implications

To communicate and control situations with theory (knowledge), a model may support how situations can be specified and sequentially developed in life cycles. This model specifies a number of sequences and suggests underlying operationalizations for each sequence. More fine-tuned studies could support more detailed operationalizations and suggest other consequences. The model should therefore not be treated as one true model but as a means for further development.

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## Appendix

### Measures

Considering following aspects of sustainability - what would you say yours work means in relationship to overall sustainability objectives. Please rate your opinion on a -3 to +3 scale. (-3=less than expressed in the goals; 0=Neutral, can not take a stand and do not know to the link between activity and goals, to; +3=more than expressed in the goals.

#### *Ecological sustainability goals (Process)*

Ecological 1: Constantly seeking alternative ways for energy efficiency (heat, water, electricity).

Ecological 2: Choosing suppliers with regard to sustainability.

Ecological 3: Choosing environmentally friendly options when purchasing.

#### *Social sustainability goals (Process)*

Social 1: Match job ads to our social standards

Social 2: Match communication materials (external and internal) with our social standards

Social 3: Work actively with gender equality within the organization.

#### *Economic sustainability goals (Process)*

Economic 1: Follow society's expectations regarding taxes.

Economic 2: Follow society's expectations regarding pensions.

Economic 3: Follow society's expectations regarding minimum salaries

#### *Sustainability performance*

With regard to sustainable performance, to what extent would you say that the organization is opposed to the organization's competitors. (There -3=worse than competitors; 0=Neutral, can not score; +3=better than competitors)

I would say that the organization is far ahead of our competitors when it comes to ...

Sustainability performance 1: Offer environmentally adapted products / services.

Sustainability performance 2: Select suppliers for durability.

Sustainability performance 3: Meeting customer expectations with sustainable ends (i.e., products / services.

#### *Sustainability consequences - index behavior 0=No; 1=Yes*

Index1: Continuously engage employees in sustainability work.

Index2: Continuously motivate employees to work actively with sustainability issues in their daily work.

Index3: Constantly relate to sustainability issues.

Index4: Regular formal meetings discussing sustainability.



Index5: Often talking about sustainability during coffee breaks.

Index6: Has clear and concrete emission targets.

Index7: Motivate employees to influence carbon dioxide emissions by their daily work.

Index8: Position climate as a central issue of sustainability.

Index9: Same work opportunities regardless of gender, ethnic orientation, religious background, age or sex.

Index10: Connect sustainability goals practical tasks.

Index11: Encourage customers to save energy in different ways.

Index12: Participate actively in sustainability conferences.

Index13: Participate actively in sustainability dialogues with other organizations in the same industry.

Index14: Sponsor local events / associations.

Index15: Information about sustainability work available.

# Health and Safety Practices in the Zimbabwean Construction Industry

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## Abstract:

The construction industry is one of the largest employers for most countries which has an impact on other downstream industries. However, it remains one of the worst industries in terms of accidents, injuries, fatalities, and disease. Yet surprisingly decisions being made daily on construction sites are generally with little regard to H&S. However, the decisions made, and the steps taken from conception stage of a project and the H&S practices adopted have a big impact on H&S performance. This research therefore explores the practices which contribute to poor construction H&S performance and the effect of poor performance on construction projects. The primary data was collected in Masvingo Province through self-administered questionnaires, and a review of NSSA records. Secondary data was collected through a review of published literature. The results of the study show that H&S performance is poor, characterized by the occurrence of accidents, injuries, and fatalities on construction projects, and non-compliance with H&S regulations. The poor performance is attributed to, inter alia, the effects of a depressed economy, fragmented H&S legislation, lack of management commitment, and lack of enforcement of legislation. The poor H&S performance in turn, adversely affects the other project parameters. Although these results are consistent with those obtained in other developing countries, they depict a situation in which the approach to H&S management is not holistic. The results of this study are expected to influence H&S awareness levels, direction, and the setting of priorities for action to improve construction H&S management in Zimbabwe and elsewhere.

*Keywords: accidents; health and safety; performance; Zimbabwe*

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## 1. Introduction

Globally, the construction industry continues to demonstrate poor performance relative to H&S outcomes. Despite several efforts by governments and stakeholders to manage H&S, the construction industry's contribution to global statistics with regards to workplace injuries, disease, and fatalities is not correspondingly changing. In Zimbabwe, the government acknowledges that the country is far from attaining the ideal level of H&S performance (National Social Security Authority (NSSA), 2015). The building and construction sector has the highest rate of H&S non-compliance with H&S provisions (Mutetwa, 2010; NSSA, 2012). The NSSA Annual Report for 2012 showed that the construction industry has 80% non-compliance with H&S provisions (NSSA, 2012). The problem is amplified by several factors, namely, lack of adequate financial provision for construction H&S; appointments of stakeholders who do not systematically manage H&S (Chigara, 2018); perception that H&S is an economic burden, which severely impinges on their already slim profit margins (WHO,

2002; Agumba and Haupt, 2009), inadequate enforcement of H&S (Sherratt et al., 2016) and the economic recession. Adequate financial provision is necessary to support sustainable construction H&S practices. The NSSA Director of Occupational Safety and Health acknowledges that the low investment in H&S, among other factors, contributed to the high incidence of occupational injury in Zimbabwe (Katongomara, 2015). Construction practices in Zimbabwe focus more on production processes and profit at the expense of H&S management and compliance (Jerie, 2012). According to Sherratt (2016), despite carefully documenting polices, hazards and risks, mitigation measures seem to be gravely lacking.

Nevertheless, the cost of workplace fatalities, injuries, and disease on workers and their families, government, and employers is enormous (ILO, 2013). The effects, which include compensation, medical expenses, lost earnings, and replacement training (ILO, 2014) play a substantial role in the spread of poverty and have a negative impact on sustainable development of a country (ILO, 2013; Chigara, 2018). It follows that much more effort must be applied through various approaches to reduce H&S incidents in the construction industry. Accordingly, this study investigated the factors influencing construction H&S performance and the effects of fatalities, injuries and disease on project parameters in Zimbabwe.

## **2. Review of the related literature**

The working environment should be designed to ensure that all hazards are either controlled, managed or eliminated within the operational parameters of the business concern. Preventive design and operational programmes are essential to ensure that favourable working conditions are created through the physical provision of an ideal working environment. In addition, the acquisition of fitting technology should receive proper attention and installation thereof to ensure adequate protection of workers from all identified H&S risks (Government of Zimbabwe, 2014).

Nevertheless, despite the link between effective H&S management and the economic benefits, H&S is often not viewed as contributing to the economic viability of an organisation. The failure to link the economic advantages of effective H&S interventions, limits the success of preventing accidents, injuries, and disease at work (Mutetwa *et al.*, 2015).

### *2.1 Determinants of H&S performance*

Despite the gain in knowledge and the various acts and regulations that exist, and which arguably should, if complied with, improve H&S performance on construction sites, numerous serious accidents continue to occur (Haupt and Pillay, 2016). Ali (2008) states that in order to ensure that satisfactory and durable results are achieved in the field of H&S in construction, each country should put in place a coherent national policy. The policy should be aimed at promoting and advancing, at all levels, the right of workers to a safe and healthy working environment; at assessing and combating at source occupational risks or hazards; and at developing a national preventive H&S culture that includes information, consultation and training. Nevertheless, in Zimbabwe the fragmentation of H&S laws (Chigara and Moyo, 2014; Moyo *et al.*, 2015; Nhokovedzo, 2017) may compromise initiatives to improve H&S performance.

Zimbabwe's occupational safety and health performance in the five years preceding the review of the National Occupational Safety and Health Policy in 2013 was not pleasing with 20 641 workers having been seriously injured and 401 of them dying from their injuries. The average injury frequency rate per 1 million hours exposure time stood at 1.64 against a standard of < 1 (less than 1). Occupational diseases' statistics within the same 5-year period are not comprehensive (Government of Zimbabwe, 2014). Furthermore, on average about 166 persons fall from scaffolding in construction in Zimbabwe each year, and of these, 3 are fatal (Mhangwa, 2018). The Government of Zimbabwe (2014) states that the national H&S performance across all sectors, inclusive of the construction sector, is far from being desirable. This poor H&S performance is attributable to several factors. The Government of Zimbabwe (2014) notes that an accident prevention culture is necessary in every workplace to stop carnage due to accidents, because employer and worker attitudes and beliefs determine how business activities are carried out at work.

H&S culture is therefore of paramount importance in the prevention of accidents and disease in any organisation (Government of Zimbabwe, 2014). These attitudes and beliefs are subsequently shaped to a larger extent by people's education, training and the level of understanding of H&S issues. Despite the very high literacy rate in Zimbabwe estimated at approximately 92% in 2013, this has not translated into a good H&S culture (Government of Zimbabwe, 2014). A study conducted by Tang (2002) concluded that H&S performance on a site varies inversely with the level of the investment in H&S. The link between effective H&S management and the economic benefits are not readily appreciated in the eyes of contractor management. The resultant outcome is often the slashing of H&S programmes by organisations in cost cutting mode, and lack of commitment to H&S. With the current economic challenges prevailing in Zimbabwe, beefing up of H&S programmes is sometimes the last optional action taken by most organisations (Mutetwa *et al.*, 2015). The problem is amplified by the downward turn of the Zimbabwean economy, which contributed to a surge in informal employment and the construction industry has not been spared. Unfortunately, informal sector workers are generally exposed to poor working environments, and poor sanitation, which translates to poor H&S performance (Government of Zimbabwe, 2014).

## *2.2 Factors contributing to non-compliance with H&S provisions*

According to Sherratt (2014), despite documenting polices and hazards and risks and detailing mitigation measures, putting these into practice is gravely lacking. In Zimbabwe, the building and construction sector has the highest rate of H&S non-compliance (Mutetwa, 2010; NSSA, 2012). Policies must be enforced. A system of inspection must be in place to secure compliance with H&S measures and other labour legislation (Ali, 2018). The current construction practice in Zimbabwe has tended to focus on production processes and profit at the expense of H&S management and compliance (Jerie, 2012). The H&S of workers is not usually viewed as a contributing factor to the economic viability of an organisation. In fact, it is viewed as a cost and bare minimum compliance with government guidelines and regulations is usually the primary focus of H&S function (Mutetwa *et al.*, 2015).

According to Lingard *et al.* (2008), contractors bear the largest portion of responsibility for construction H&S. Unfortunately, dependence on contractor-centric H&S management has not yielded the required results (Chigara and Smallwood, 2016). The problem is further compounded by lack of government commitment (Mwanaumo *et al.*, 2014; Mwombeki, 2006 in Chiocha *et al.*, 2011), bribery, corruption, and political interference (Okorie *et al.*, 2014; Chigara and Moyo, 2014; cidb, 2011).

### 2.3 *The cost of accidents (CoA)*

By their very nature accidents are undesirable events given their resultant unpleasant and damaging consequences (Haupt and Pillay, 2016). Mutetwa *et al.* (2015) echo the same sentiments, and state that workplace fatalities, injuries, and disease remain an unnecessary burden on the country's workforce, companies, and society. The calculated costs of construction accidents to a large extent represent the losses incurred by a construction organisation (Tang *et al.*, 2004). The financial impact of costs such as lost productivity and overtime has been estimated by the 2002 Safety Index of Liberty Mutual to be as much as \$240 billion. Direct workers compensation costs in the United States were estimated to be \$48.6 billion for the most disabling workplace injuries and illnesses in 2006. By adding the indirect cost of workers' compensation claims to the \$38.7 billion in direct costs, the total economic burden of workplace injuries and illness is far greater, with estimates ranging between \$125 billion to \$155 billion (Haupt and Pillay, 2016). In Southern Africa, the cost of workplace accidents is estimated to be 3% of GDP in Zimbabwe (Loewenson, 1999) and 3.5% of GDP in South Africa (Republic of South Africa cited in Musonda *et al.*, 2013).

The existing evidence indicates that workers and their families bear the greatest burden of workplace accidents (Safe Work Australia, 2015; HSE, 2015). According to the HSE (2015) in Chigara and Smallwood (2018), the workers bear 57 % of the costs, followed by government at 24 %, and employers at 19 % (HSE, 2015). According to Dembe (2001), injured workers suffer from disruption in working lives / loss of employment, loss of income, and must meet medical and rehabilitation expenses. The costs suffered by employers include payments to workers who have suffered injuries, insurance costs, staff turnover cost, loss of productivity, and loss of property (Sun and Zou, 2010; Safe Work Australia, 2015). Whereas the burden to society arises from programmes to indemnify workers, compensation, rehabilitation, and loss of human capital (Sun and Zou, 2010; Safe Work Australia, 2015). According to Okoye and Okolie (2014), the importance of the H&S of construction workers can never be over emphasised, because when accidents happen on site, they cause many human tragedies, demotivate workers, disrupt site activities, delay project progress, and affect overall project cost, productivity, and the reputation of the firms concerned.

The synergy between H&S and the other project parameters is important and a project cannot realise success without adequate H&S (Smallwood and Emuze, 2004). It is imperative to note that productivity, cost, client perception, environment, and schedule are negatively impacted by inadequate H&S (cidb, 2009). H&S failure spells catastrophic overall failure for a project.

### 3. Research method

The research adopted a quantitative research approach wherein forty-five (45) structured questionnaires were administered to construction practitioners working for contractors, construction consultants, a regulatory agency, and central and local government in Masvingo Province. The quantitative research method was chosen because of a vast array of advantages. According to Leedy and Ormrod (2015), a quantitative approach allows a researcher to isolate the variables one wants to study and use a standardised procedure to form numerical data and apply statistical procedures to analyse and draw conclusions from the data. Simple random sampling was used to select survey respondents. Quantitative analysis was done using Microsoft Excel, producing descriptive statistics, which entailed the computation of percentages, and a measure of central tendency in the form of a mean score (MS).

### 4. Research findings and discussion

#### 4.1 Demographic profile of the respondents

A total of 34 questionnaires, representing a 75.6% response rate, were successfully completed and analysed. The completed questionnaires were received from central government departments (26.5%), designers (11.8%), local authorities (8.8%), and contractors (52.9%). The occupations of the respondents were as follows: artisans (bricklayers, plumbers, electricians, tilers, carpenters) (41.1%), engineers (11.8%), housing officers /building inspectors (11.6%), construction supervisors or foremen (8.8%), H&S Inspectors (8.8%), quantity surveyors (5.9%), architects (5.9%), and general workers (2.9%). The respondents' work experience spanned from 9 months to 37 years, and the mean work experience was 14.5 years. The qualifications of respondents are as follows: Master's Degree (11.8%), Honours Degree (17.6%), Higher National Diploma (8.8%), and National Diploma (11.7%), National Certificate / artisan certificate (41.2%), and Grade 7 (8.8%). The demographic analysis shows that the respondents had relevant experience and knowledge to provide valid and reliable assessments of the issues raised in questionnaires.

#### 4.2 The construction H&S situation in Zimbabwe

Table 1 presents the statements relative to construction H&S in Zimbabwe and the degree of concurrence with such statements in terms of percentage responses to a scale of 1 (strongly disagree) (SD) to 5 (strongly agree) (SA), and a MS ranging between 1.00 and 5.00, the midpoint score being 3.00. It is notable that all the statements have MSs > 3.00, which indicate that respondents agree as opposed to disagree with the statements.

**Table 1. Degree of concurrence with statements relative to H&S**

Statement	Response (%)					MS	Rank	
	Un- sure	SD	SA	1	2			3
Injuries occur on construction sites	3.1	0.0	6.3	9.4	65.6	21.9	4.13	1
Accidents happen on construction sites	0.0	0.0	5.9	5.9	61.8	26.5	4.09	2
H&S performance is poor	3.1	0.0	6.3	25.0	46.9	26.0	4.00	3
There is inadequate awareness of H&S issues in the industry	3.1	0.0	9.4	25.0	50.0	18.8	3.88	4
There is non-compliance with H&S provisions on construction projects	0.0	0.0	5.9	26.5	47.1	20.6	3.82	5
Fatalities occur on construction sites	0.0	0.0	5.9	29.4	47.1	17.6	3.76	6
Plant and equipment are susceptible to accidents on sites	0.0	8.8	5.9	11.8	52.9	20.6	3.71	7

It is notable that all the statements have MSs  $> 3.40 \leq 4.20$ , which indicate that respondents concur with the statements between a neutral to agree / agree. The results indicate that construction H&S performance is poor in Zimbabwe as demonstrated by the occurrence of injuries, accidents, injuries and fatalities, and non-compliance with H&S regulations and provisions. The results reinforce the earlier observations by the NSSA (2012) that non-compliance in the construction industry in Zimbabwe is above 80%. The results highlight the need to investigate the factors contributing to the current H&S situation in Zimbabwe so as to guide the interventions to improve the situation.

#### 4.3 Factors influencing H&S performance in Zimbabwe

Table 2 shows the respondents' assessment of the extent to which six factors adversely influence H&S performance in Zimbabwe in terms of percentage responses to a scale of 1 (not at all) to 5 (major), and a MS ranging between 1.00 and 5.00, the midpoint score being 3.00.

**Table 2. Extent to which six factors adversely influence H&S performance in Zimbabwe**

Factor	Response (%)					MS	Rank	
	Un- sure	Not at all	Major	1	2			3
A depressed economy	0.0	0.0	8.8	14.7	14.7	61.8	4.29	1
Fragmented H&S legislation	5.9	0.0	2.9	41.2	23.5	26.5	3.74	2
Lack of management commitment	2.9	2.9	8.8	23.5	29.4	32.4	3.71	3
Lack of H&S training	2.9	0.0	11.8	17.7	41.1	23.5	3.71	3
A lack of awareness of H&S issues	2.9	0.0	8.8	29.4	26.5	32.4	3.56	5
A negative H&S culture	0.0	2.9	14.7	26.4	29.5	26.5	3.62	6

Given that the MSs for all the factors are above the midpoint score of 3.00, the results indicate that respondents deem the factors to have a major as opposed to minor effect on H&S performance. It is notable that 'a depressed economy' is ranked 1<sup>st</sup> with MS = 4.29, which indicates that respondents perceive that 'a depressed economy' adversely affects H&S between a near major to a major / major extent. The results suggest that economic performance has a major effect on construction H&S performance in Zimbabwe. Zimbabwe's economy continued to decline since 2000 and from a H&S standpoint, conditions deteriorate fast when the economy

is not performing, as the maintenance of machinery is postponed, the supply of PPE is deferred, and injuries reign. The results are consistent with previous studies (Chigara, 2018; Nhokovedzo, 2017, Tang, 2004), which determined that H&S performance on a site varies inversely with the investment in H&S.

The factors ranked 2<sup>nd</sup> to 6<sup>th</sup> have MSs > 3.40 to ≤ 4.20, which indicates that the factors influence H&S performance between a moderate to a near major / near major extent. The factors / variables in this range include: ‘a fragmented H&S legislation’, ‘lack of management commitment’, ‘lack of training’, ‘a lack of awareness of H&S issues’, and ‘a negative H&S culture’. The absence of a composite and comprehensive set of regulations for H&S poses a big administrative problem with regards to implementation of better H&S practice. This problem may lead to confusion in the jurisdiction of authority on the administration of law. The results further reinforce previous studies (Chigara and Moyo, 2014; Moyo *et al.*, 2015; Nhokovedzo, 2017) which highlighted that the fragmentation of H&S laws may compromise initiatives to improve H&S performance. The Government of Zimbabwe (2014) state that H&S culture is of paramount importance in the prevention of accidents and diseases in any organisation.

#### 4.4 Factors contributing to non-compliance with H&S provisions

Table 3 shows the respondents’ assessment of the extent to which selected factors contribute to non-compliance with H&S provisions on construction projects in terms of percentage responses to a scale of 1 (not at all) to 5 (major), and a MS ranging between 1.00 and 5.00, the midpoint score being 3.00.

**Table 3. The extent to which eight factors contribute to non-compliance with H&S provisions**

Factor	Response (%)						MS	Rank
	Un- sure	Not at all .....				Major		
		1	2	3	4	5		
A depressed economy	0.0	11.8	8.8	17.7	17.7	44.1	3.76	1
Inadequate H&S inspection	0.0	2.9	14.7	17.7	32.4	32.4	3.74	2
Lack of contractor commitment	0.0	5.9	5.9	23.5	44.1	20.9	3.68	3
Corruption (including bribing of NSSA officials)	2.9	8.8	0.0	29.4	52.4	26.5	3.59	4
Inadequate enforcement by the NSSA	0.0	8.8	8.8	26.5	29.4	26.5	3.56	5
Lack of Government commitment	0.0	14.2	17.7	8.8	23.5	35.3	3.47	6
Lack of qualified H&S inspectors for the construction industry	0.0	8.8	20.6	23.5	26.5	20.6	3.29	7=
Lack of H&S awareness	0.0	8.8	23.5	20.6	23.5	23.5	3.29	7=

It is notable that all the factors have MSs > 3.00, which indicates that respondents deem that the factors contribute to non-compliance with H&S provisions to a major, as opposed to minor extent.

The factors / variables ranked 1<sup>st</sup> to 6<sup>th</sup> have MSs > 3.40 to ≤ 4.20, which indicates that respondents deem the factors contribute to non-compliance with H&S provisions between a moderate to a near major / near major extent. The results indicate that ‘a depressed economy’ ranks 1<sup>st</sup> among the factors contributing to non-compliance with H&S. Due to the economic recession, investments in H&S and maintenance of machinery are deferred until disaster strikes. The ILO states that investment in H&S tends to suffer during periods of economic recession.



In addition to the impact of the economic recession, respondents also perceive inadequate compliance with H&S arises as a result of inadequate H&S inspections, corruption, inadequate enforcement by the NSSA, and lack of commitment from central government. The results reinforce the importance of a multi-stakeholder approach to H&S management. During a previous study, Chigara and Moyo (2014) observed that poor economic performance, inadequate enforcement of H&S provisions by NSSA, lack of contractor commitment and corruption, as some of the factors contributing to non-compliance with H&S provisions. The problem is further compounded by lack of government commitment (Mwanaumo et al., 2014), bribery, corruption, and political interference (cidb, 2011; Okorie et al., 2014; Chigara and Moyo, 2014).

#### 4.5 The impact of construction accidents

Table 4 presents the effect of workplace fatalities, injuries and disease on workers and their families, the project, and the construction enterprises in terms of percentage responses to a scale of 1 (not at all) to 5 (major), and a MS ranging between 1.00 and 5.00, the midpoint score being 3.00.

**Table 4. The extent of the effect of workplace fatalities, injuries, and disease in terms of fifteen factors**

Factor	Response (%)					MS	Rank	
	Un-sure	Not at all	1	2	3			4
Pain, stress and family problems to workers	0.0	0.0	5.9	17.7	26.5	50.0	4.21	1
Financial difficulties to workers and their families	2.9	0.0	8.8	17.7	20.6	50.0	4.03	2
Injuries	0.0	2.9	11.8	11.8	14.7	55.9	4.03	2
Reduce productivity	0.0	5.9	11.8	11.8	29.4	41.2	3.88	4
Worker disablement	2.9	2.9	11.8	14.7	23.5	44.1	3.85	5
Lost time	0.0	8.8	8.8	20.6	26.5	38.2	3.79	6
Reduce workers' morale	0.0	5.9	5.9	11.8	20.6	47.1	3.79	6
Rework	0.0	0.0	17.7	14.7	35.3	26.5	3.59	8
Compromise company's image	0.0	14.7	14.7	8.8	8.8	50.0	3.56	9
Damage to plant and equipment	0.0	17.7	11.8	17.7	23.5	29.4	3.35	10
Penalties	0.0	5.9	20.6	29.4	11.8	29.4	3.32	11
Damage to materials	2.9	14.7	17.7	20.6	11.8	35.4	3.21	12
Standby costs	5.9	2.9	23.5	32.4	17.7	17.7	3.06	13=
Damage to structure and work in progress	2.9	8.8	23.5	17.7	23.5	20.6	3.06	13=
Clean up costs	17.7	14.7	14.7	29.41	14.7	8.82	2.35	15

It is notable that 14 of the 15 factors have MSs greater than 3.00, which indicates that respondents deem the effect of workplace fatalities, injuries, or disease to be major as opposed to minor. The results indicate that workplace fatalities, injuries, or disease result in 'pain, stress and family problems to workers' (MS = 4.21) between a near major to a major / major extent.

The variables ranked 2<sup>nd</sup> to 9<sup>th</sup> have MSs > 3.40 to ≤ 4.20, which indicates that respondents deem that workplace fatalities, injuries, or disease contribute to the occurrence of financial difficulties to workers and their families, reduced productivity, worker disablement, lost time,

reduced workers' morale, the occurrence of rework, and compromise company's image between a moderate to a near major / near major extent.

The results indicate that the variables ranked 10<sup>th</sup> to 13<sup>th</sup> have MSs > 2.60 to ≤ 3.40, which indicates that respondents deem that workplace fatalities, injuries, or disease contribute between a near minor to a moderate / moderate extent to the occurrence of damage to plant and equipment, penalties, damage to materials, standby costs, and damage to structure and work in progress.

The variable ranked 14<sup>th</sup> has a MS > 1.80 to ≤ 2.60, which indicates that respondents deem the effect of workplace fatalities, injuries, or disease to contribute to cleaning up costs to be between a minor to a near minor / near minor extent.

The findings highlight the need for adequate construction H&S management. The costs of inadequate H&S are enormous and affect several stakeholders. The results indicate that inadequate H&S has both social and economic effects on workers, the enterprise, and government / society. At the enterprise / project level, the economic costs of accidents include reduced productivity, the occurrence of reworks, penalties, and damage to plant, equipment, materials and work in progress. To workers and their families, workplace incidents cause pain and suffering, reduce moral, contribute to financial problems, and contribute to disabling injuries. A study conducted by Dembe (2001) indicated that injured workers suffer from disruption in working lives / loss of employment, loss of income, and must meet medical and rehabilitation expenses. Nevertheless, the costs of accidents can be reduced by taking a proactive approach to H&S management. Previous studies (Emuze and Smallwood, 2014) indicate that the cost of accident prevention / investing in H&S is less than the costs of accidents.

#### 4.6 The impact of inadequate H&S on the other project parameters

Table 5 shows the respondents' assessment of the impact of inadequate H&S on four project parameters in terms of percentage responses to a scale of 1 (not at all) to 5 (major), and a MS ranging between 1.00 and 5.00, the midpoint score being 3.00.

**Table 5. The impact of inadequate H&S on the other project parameters**

Parameter	Response (%)					MS	Rank	
	Un- sure	Not at all	.....	Major				
	1	2	3	4	5			
Schedule (Time)	2.9	0.0	8.8	17.7	17.7	52.9	4.36	1
Cost	2.9	0.0	11.8	11.8	35.3	38.2	4.00	2
Quality	5.9	0.0	11.8	17.7	29.4	35.3	3.85	3
Environment	2.9	8.8	5.9	29.4	17.7	35.3	3.59	4

The results indicate that all the MSs > 3.00, which indicate that respondents deem the impact of inadequate H&S on project parameters to be major as opposed to minor. The MS of 4.36 for 'project schedule (time)' indicates that respondents perceive that inadequate H&S affects project schedule (time) between a near major to a major / major extent. The factors ranked 2<sup>nd</sup> to 4<sup>th</sup> have MSs > 3.40 to ≤ 4.20, which indicates that inadequate H&S affects project

cost, quality, and the environment between a moderate to a near major / near major extent. In addition to adversely affecting the traditional project parameters, the results indicate that inadequate H&S also affects the environment. During a previous study, Chigara and Smallwood (2016) determined that inadequate H&S adversely affected project parameters in Zimbabwe. In addition, the results further highlight the synergy between H&S and other project parameters (Smallwood and Emuze, 2014). The research findings indicate that project success may not be realised without adequate H&S.

## **5. Conclusions and further research**

This study determined that the responsibilities of government, employers, and workers should be seen as complementary and mutually reinforcing in the common task of promoting occupational safety and health to the greatest extent possible within the constraints of national conditions and practice. However, a depressed economy, fragmented H&S legislation, lack of management economy, inadequate enforcement, corruption, a negative H&S culture, a lack of inspectors, a lack of training and education, inadequate provision for H&S the major factors affecting H&S in Zimbabwe. In addition, the study results indicate that that inadequate H&S has adverse effects relative to construction firms, workers and society. The study determined that the occurrence of workplace fatalities, injuries or disease exert enormous pain of the workers, contribute to financial challenges, reduce productivity, contribute to the occurrence of reworks, and cause damage to property. The results highlight the importance of involving all stakeholders who have a bearing on H&S management along the construction supply chain management. It follows that much more effort must be applied through various approaches to ensure that workers return home safe after a day at work. This research therefore recommends a harmonization of H&S legislation and formation of legislation to compel contractor management commitment and compliance with H&S legislation.

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# Designing for Sustainability Governance Implementation in Infrastructure Delivery Systems: Success Factors

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## **Abstract:**

Infrastructure delivery processes possess the potential of negatively influencing sustainability. To curb the incidence of such negative influences within infrastructure delivery systems, the enthronement of an effective governance framework becomes imperative. Efforts have been dissipated on process transformation towards sustainability. These innovations have focused on the technical aspects of process transformation without recourse to commensurate managerial and governance praxes. The seeming inability of these pro-sustainability initiatives to deliver on expected outcomes has been attributed to this lapse. Scholars advocate an alignment of these technical factors with the right mix of managerial and governance competencies. This has led to the emergence of literature on sustainable project management practice. But studies seeking to modify extant project governance structures in like manner remain scant. This study contributes to this emerging discourse on the utility of project governance competencies in facilitating sustainable infrastructure delivery. To achieve this objective, this study identifies critical success factors central to the design of effective sustainability governance structures of a typical ID system with the assistance of a cybernetic system framework- the Viable Infrastructure Delivery systems Model (VIDM). Adopting a qualitative multi-case study research design, this study deploys semi-structured interviews for data elicitation through purposively sampled interviewees within the identified cases and, document review. Qualitative Content Analysis (QCA) was deployed for data analysis. Findings from this study provide critical success factors for designing effective sustainability governance structures of ID systems. It is expected that the findings from this study will contribute to the emerging discourse concerning sustainability governance of ID systems.

**Keywords:** *critical success factors; infrastructure delivery; sustainable development; sustainability governance*

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## **1. Introduction**

The rising demand for adequate infrastructure stock is taking a toll on the natural ecosystem (Swilling, 2006, Vives et al., 2009, Willetts et al., 2010). Also, the quick pace of technological transformations experienced in contemporary society places undue pressure on infrastructure client organizations (ICOs) to devise ways to modify or provide the infrastructure which is compatible to such transformations in like pace. Contributing to the increased investment in infrastructure being witnessed globally is the famed nexus between the availability of infrastructure and economic growth (Esfahani and Ramírez, 2003). The latter is reportedly the case with developing countries where efforts to improve the infrastructure stock has occupied centre-stage of national developmental discourse. However, the aspirations for improved infrastructure stock is confronted with the challenge of delivering these assets in a manner that

is congruent with comprehensive adherence to sustainable development goals (SDG) tenets. This implies that participants to the delivery of an infrastructure asset must ensure compliance with pre-determined parameters of the three sustainable development dimensions, namely; social, environmental and economic dimensions, albeit in an integrated manner. Obviously, this will require trade-offs and compromises depending on what dimensions the parties to the Infrastructure Delivery (ID) system decide to prioritize above the rest.

Over the years, the construction and infrastructure industry has acquired a time-honored reputation for posting debilitating effects on the environment and society in different ways (Shaw et al., 2015). According to extant studies, the construction industry and its products such as critical infrastructure and the built environment have made salient contributions towards undermining the sustainable development agenda (Kibert, 2016). Yet, the industry through its products has also provided initiatives for developing sustainable built environments. As such, the challenge is on how to ensure that the industry transforms itself in a way that will only engender the delivery of pro-sustainability products in a sustainable manner. Little wonder the industry has been at the forefront of repudiating this reputation through the development of various innovative solutions. One of such solutions is the concept of sustainable construction. According to Sfakianaki (2015), sustainable construction is predicated on the attainment of economic efficiency, improved environmental performance and social responsibility across facets like adaptable/flexible building design and construction, enhanced material performance, innovative operations and maintenance schedules, innovative financing models, energy and resource efficiency, increased stakeholder participation and involvement, lifecycle analysis of projects, etc. Also, proponents of another innovative concept (Lean Construction) insist on its potential to reduce the incidence of non-value adding activities (waste) within the construction supply chain (Tommelein, 2015, Babalola et al., 2018). Most recently, the concept of the circular economy has evolved into societal consciousness. This concept deals with effectuating, among other aspects, the principles of industrial symbiosis, extended producer responsibility as well as extended product useful life (Nasir et al., 2017, Geissdoerfer et al., 2017). This concept has been lauded as providing a cogent pathway for the attainment of sustainability across different economic sectors. A perfunctory appraisal of these solutions amongst a plethora of others indicates a fixation on processes (technicalities) without regard for the managerial competencies required to drive them to fruition. Also, there is a seeming paucity of studies seeking to the investigation into the nature of governance approaches required to facilitate the successful implementation of these processes. The successful implementation of strategic and/or project objectives require a juxtaposition of social and technical aspects.

Literature confirms the emergence of a school of thought soliciting for the integration of sustainable development principles into project management competencies toolkit within and beyond the realm of construction projects (Silvius, 2013, Silvius and Schipper, 2014). According to proponents of this school, the contemporary project manager needs to possess skillsets beyond that which is expected to attain project management success but engender project success (Banihashemi et al., 2017, Marcelino-Sádaba et al., 2015). This implies the addition of sustainability and functionality-based set of performance indicators to the conventional indicators like time, cost and quality. Whereas studies seeking to advance this course of thinking are on the rise, nothing seems to be going on with regards to the incorporation

of sustainability tenets into project governance within the realm of construction projects delivery, to the best of the authors' knowledge. Although the existence of studies into sustainability governance and/or the governance of sustainable development is noted, such studies do not concern themselves with construction and infrastructure projects delivery. Considering the instrumentality of project governance structures to project success, it has become imperative to investigate the utility of existing project governance approaches in embedding SD ethos across different phases of the project (infrastructure) delivery lifecycle. Whilst this study seeks to contribute to this appraisal, it concerns itself with laying the foundation of such inquiry through an identification of the critical success factors for designing effective sustainability governance structures of ID systems.

The rest of this paper will be structured as follows: A review of state-of-the-art literature on sustainability governance in ID systems and, an exposé on the Viable Infrastructure Delivery Systems Model's (VIDM's) utility for appraising project governance structures within ID systems; justification of the research methods adopted; the presentation and discussion of findings, and; a conclusion.

## **2. The Concept of Sustainability Governance in Infrastructure Delivery System**

A plethora of views concerning the meaning of governance exists in the literature. Yet, to gain an extensive insight into the connotation of the concept of sustainability governance, there is a need to define governance and project governance. Significant among the various connotations of the governance concept is the view held by Türke (2008) wherein the scholar proposes that the concept of governance be considered from a systems perspective. According to him, such a system comprises of the duo of a structure and actor-oriented perspective serving as two disparate modes of governance. Continuing, Türke (2008) postulates that the former perspective is concerned with the belief that social systems are self-governing and independent objects which govern themselves through circular, self-referential processes which highlight their identity. However, the actor-oriented perspective views social systems as comprising of communications between actors with the actors serving as empirical sub-units. Apparently, this understanding implies that governance involves systems and actors working within inter-organizational networks in a self-organizing manner (Shiroyama et al., 2012).

The views elucidated previously concerning governance does not differ from those accorded to the concept within the realm of construction and infrastructure project delivery. However, the point of departure lies in the notion that the dyadic relationships existing between actor-actor and/or actor-structure are both characterized by its transactional nature. To buttress this, Winch (2001) situates the concept of project governance along two sides of a continuum; firstly, as processes associated with transactions between actors in a project and secondly, as transactions between institutions at the level of the society. Taking a closer and more specific insight into the concept of project governance, Cooke-Davies et al. (2009) maintain that project governance consists of a series of institutionalized principles, structures as well as processes for administering to projects. Being considerably different from project management, project governance details in its entirety, all the processes and actors involved in the project delivery process spanning across multiple scales and not just the project environment (Awuzie and Ngowi, 2017). As such, it facilitates the linking of strategic objectives behind the project and



the actual implementation of these objectives at the project level through the efficacy of the structures and alignment of actors. These structures and processes include: contracts between actors, defined procurement strategy and pathways, risk allocation and management, monitoring and coordination of work during various phases of the project lifecycle, processes for collaboration among project stakeholders as well as the nature of communication between actors (Ahola et al., 2014).

The procurement and delivery of infrastructure assets is a complex undertaking. Its complexity is heightened by the multiplicity of parties involved as well as the time and cost constraints within which it must be delivered. Also, the socio-economic and environmental implication of its failure is one that is rather imagined than witnessed. This makes the institution of effective governance and management frameworks imperative. An infrastructure delivery (ID) system has been described as a representation of all types of interorganizational and multi-layered relationships between various project actors during the delivery of the infrastructure asset as well as the tendencies these parties bring upon the project (Awuzie and McDermott, 2015).

It has been reiterated that the aim of a governance framework includes the attainment of the strategic objectives upon which the initiation of the project was predicated (Lizarralde et al., 2013). Recently, ICOs are publicly committing to sustainable procurement and project delivery. Suddenly, ICOs are asking their ID systems to conform to and deliver projects according to SD ethos. Such requests are intended to boost the ICOs pro-sustainability reputation whilst also supporting competitiveness in the marketplace. Obviously, the adoption and utilization of the appropriate governance framework will assist ID systems to deliver on this mandate. Yet, a cursory look across the globe reveals that projects are still being delivered in a manner akin to business as usual. This is especially the case in developing countries like Nigeria and South Africa where the need for new infrastructure is paramount. Scholars have attributed this observation to the inability of the extant governance approaches to deliver on SD mandates and solicited for the incorporation of SD ethos into these governance frameworks or perhaps the development of new sustainability governance frameworks for ID systems as a probable panacea. Corroborating these scholars, (Ayre and Callway, 2013) insist that the ability of a project to deliver on sustainability outcomes is largely dependent on the mode of governance adopted. But, Lange et al. (2013) assert the absence of an appropriate governance framework for governing sustainability in projects and society. This makes the study of sustainability governance from the perspective of ID systems imperative.

The concept of sustainability governance defies a widely accepted definition in the literature. However, Shiroyama et al. (2012) presents a most succinct definition which is appropriate for this study's context. The authors present sustainability governance as an assemblage of formal or informal networks existing between actors and the systems within which these networks are domiciled, that affect sustainability through the integration of various dimensions, culminating in the integration of distinct knowledge bases as well as multi-actor perspectives. Such integration enables the attainment of a consensus on what SD dimensions to prioritize across the project lifecycle. However, the absence of such a governance framework stands to negate sustainable project delivery and even more so, the working of ID systems. In

reiterating the need for such frameworks to be designed and applied, Kemp et al. (2005) outline various factors for the actualization of these frameworks. These factors include; internalization of external costs, integration of policy considerations within the delivery system, development of common and shared SD objectives, selection of suitable sustainability-based criteria for planning as well as widely accepted indicators for measuring actionable progress towards sustainability, agreement concerning trade-offs, provision of information concerning available incentives for practical implementation and development of programmes for continuous system innovation. For effective sustainability governance to be entrenched in construction project delivery systems such as ID systems, certain features such as effective partnerships within networked systems, imbued with significant degrees of reflexivity, participation, adaptability, social learning processes as well as knowledge integration and multi-actor management appear imperative (Awuzie and Ngowi, 2017). Yet, designing for systems with these characteristics require an understanding of critical success factors which will facilitate smooth adoption and implementation thereby fostering effective sustainability governance within ID systems. This is what this study seeks to achieve through an identification of the success factors required for the design and development of workable sustainability governance frameworks for ID systems from the perspectives of the relevant parties working within the context.

### *2.1 The Viable Infrastructure Delivery Systems Model (VIDM)*

The viable infrastructure delivery systems model (VIDM) is a toolkit for the appraising and/or diagnosing the ability of ID systems to attain and maintain viability (Awuzie and McDermott, 2015). Viability is described as an organizational attribute which enables organizations to adapt to their selected environment or better still, adapt their environment to suit their internal structures (Hoverstadt, 2011). In the case of ID systems, viability would imply the system's ability to deliver an infrastructure project in a sustainable manner despite external and internal challenges (Awuzie and McDermott, 2015). Besides this, the VIDM enables a proper conceptualization of inter-organizational relationships existing within the ID system as well as the responsibilities of the actors within the conceptualized model. Derived from the viable systems model (VSM) and its underlining principles, the VIDM provides a structured methodology for deciphering the ability of the governance structure in an ID system to deliver on SD mandates. Its ability to perform this diagnosis is premised on an establishment of the presence of 6 related functions within the ID system. These functions are as follows: operation, coordination, control, monitoring\*, intelligence, and policy, respectively. The presence of these factors remains imperative for enabling effective sustainability governance. Figure 1 shows a typical VIDM for an ID system during and, at the end of the project delivery cycle.

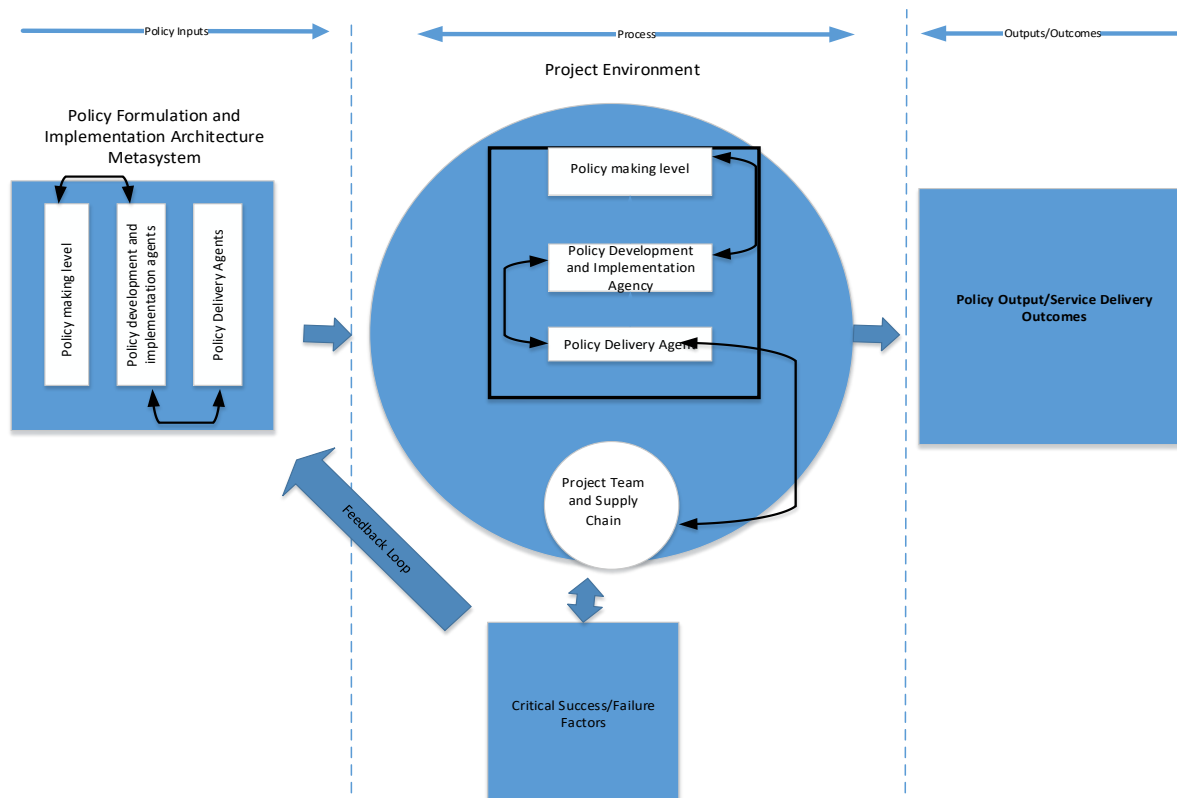


Figure 1. A Typical VIDM (Adapted from Awuzie and McDermott, 2015; 2019)

However, in the VIDM, these subsystems have been appropriately named to reflect the governance structure present within ID systems. This information is provided in Table 1.

Table 1. Comparison of terms used in VSM and VIDM

Subsystem	VSM	VIDM
5	Policy	Policy making level (Enabling government policy)
4	Intelligence	Policy development, implementation, and regulatory agencies
3/ 3*	Control / Monitoring	Project Departments (Infrastructure Client Organization)
2	Coordination	Contractor/ Project Management department (Infrastructure client organization)
1	Operations	Project environment (Project team and Supply chain)

As observed from Figure 1 and Table 1 respectively, the VIDM's metasystem (the bounded area with thick borders) happens to be responsible for the following tasks; project conceptualization, initiation, control and monitoring, and some aspects of the project coordination and implementation. This confirms the significant position wielded by the ICO in engendering optimal project governance and, by extension project success.

Figure 1 attests to the complexity of ID system due to the multiplicity of organizations that are involved with the delivery process. Such complexity tends to negate attempts at embedding SD ethos into the processes inherent in the ID system. Also, policy initiatives leading to the conceptualization of these infrastructure projects and associated SD deliverables tend to be lost in this complexity and are not considered and/or implemented at the project level. This has been described as a salient contributor to the rising levels of ICO dissatisfaction being experienced concerning the functionality of delivered projects and the ability of these projects to achieve the original goals- this has been labelled as a policy or strategy disjuncture (Adham et al. 2012). Also, a lot of SD aspects are difficult to measure especially during infrastructure delivery and ICOs only have to wait to the end of the delivery period and commissioning to appraise the deliverables. This poses a challenge for these ICOs as considerable investments will have been made in the projects for the purpose of achieving these SD aspects in the first instance. The VIDM, when succinctly deployed, enables a conceptualization of the relationships existing between various stakeholders, highlighting their responsibilities and the communication channels between them. Such conceptualization engenders effective governance of the ID system thus allowing for traceability and accountability in the system as it concerns the implementation of SD ethos during the delivery period.

Based on the foregoing, the utility of the VIDM in facilitating effective governance can be deduced. However, the VIDM is just a toolkit and can be modified to serve different governance-related deliverables. As such, when developing a VIDM to facilitate sustainability governance in an ID system, there is a need to identify the critical success factors influencing the toolkit design. Previous studies have explored the failure and success factors affecting the implementation of the socio-economic policy (as well as other policies) objectives through ID systems (Awuzie and McDermott, 2019). However, this study seeks to identify the critical success factors for designing VIDMs to engender effective sustainability governance of ID systems.

### **3. Research Method**

This study adopts a qualitative multi-case study research design. The choice of this design was based on its usefulness for carrying out an in-depth study into a phenomenon within its natural environment. Scholars like Bryman (2003) and Hartley (2004) have reiterated the suitability of the case study research design for conducting research within organizations. The ID system doubles as an organization albeit a temporary multi-organization (de Blois and Lizarralde, 2010, de Blois et al., 2016). Of importance to the authors during the selection of a research design was the ability to deploy a plethora of tools for data elicitation. The capability of the case study research design in this regard is legendary (Yin, 2013). Accordingly, data was collected through a mix of semi-structured interviews and document reviews.

The case selection criteria were designed to allow for analytical generalization of the study's findings. The principles of replication (theoretical and literal) logic were applied during the selection of cases (Yin, 2013). In consideration of the foregoing, the selection criteria for case selection was narrowed to three, namely: The ID system being selected must be active, i.e. either presently involved in the delivery of infrastructure or recently disbanded following the completion of an infrastructure project; the infrastructure project must comprise of civil works,

i.e. roads, buildings, storm water drainages, etc., and, finally, the business cases for the project must outline the embedding of aspects of SD ethos as part of the programme or project deliverable. In addition to this, the effort was made to ensure variance in project size in some ways to enable replication. The authors got access to the ID systems through the ICOs. Indeed, this proved beneficial as it enabled for access to members of the supply chain. Also, the authors had a list of projects to choose from. The rationale behind the choice of recently completed projects was to allow for access to representatives of participating organizations who had moved on upon project completion. Furthermore, the VIDM provided the authors with a platform for mapping these representatives-turned interviewees on its subsystems. ID system as presented through the VIDM served as the study's unit of analysis. A brief background of the case characteristics is provided in Table 2.

Table 2. Project Cases

Case studies characteristics	Case Study 1	Case Study 2	Case Study 3
Country	Nigeria	Nigeria	Nigeria
Sector	Transportation	Education (School Building)	Education (School Building)
Value	>1b	<1b	<1b
Ownership of ICO	Public	Public	Private
Status	Ongoing (70% Completed)	Recently Completed (February 2019)	Recently Completed (October 2018)
The mandate for SD deliverables	Yes	Yes	Yes

Based on the information in Table 2, three case studies were sourced from different economic sectors and belonged to different value bands. Also, the projects selected had mandates for SD deliverables. However, it is pertinent to note that the study being reported in this paper forms part of an on-going wider study. As such, the three cases reported here forms part of 12 case studies selected from four Sub-Saharan African countries; Nigeria, Angola, South Africa, and Ghana. It is expected that the findings from the broader study will be validated against the propositions raised in Lizarralde et al. (2013) concerning the nuances in construction project governance in developing and developed countries through a survey with stakeholders in the developed country context. Table 3 highlights the number of interviewees per case study, showing the VIDM subsystems to which they belong.

Table 3. List of Interviewees

VIDM Subsystem	Number of Interviewees Case Study 1	Number of Interviewees Case Study 2	Number of Interviewees Case Study 3
5	Policy Document	Policy Document	Policy Document
4	3	1	1
3 / 3*	1	1	2
2	1	3	1
1	2	3	2
Total	7	8	6

Access to the ID systems serving as case studies on this project was gained through prior correspondence with the gatekeepers. These gatekeepers were informed of the significance of the study, especially as it concerned the incorporation of SD tenets in delivery systems and the benefits thereof. The semi-structured interviews were conducted at different intervals between September 2018 and March 2019 at the offices of the various organizations and on Skype. The interview sessions lasted for an average of 40 minutes and were tape-recorded with the permission of the interviewees. The interviewees were sent a note, two-weeks prior to the scheduled interview sessions, providing a detailed background of the sustainability governance of ID systems concept. The 2-week window was availed to those who were unsure to seek for further clarification from the first author through informal chats. During this process, a reduction in the number of prospective interviewees was observed. As such, only those who indicated an appreciable level of understanding of the concept showed interest in continuing with the sessions.

Questions asked during the interview sessions ranged from, the understanding of the concept of sustainability and SD, the level of satisfaction of clients concerning the delivered asset from a sustainability perspective, understanding of project governance and the distinction between governance and management, an identification of project-based activities which could deter the attainment of sustainability on projects, knowledge of the 3P (portfolio, programme and project) and the nexus thereof. Also, of interest to the interviewer was the interviewees' understanding of strategy and their experiences of project-level implementation of strategy/policy, particularly SD-related strategy/policy. Discussions around these aspects provided robust data sets from the sessions. The first author acted as an interviewer for the reported cases, whereas all authors independently reviewed the transcripts and meet at intervals to discuss the outcomes of their individual interpretation of the data. This sensemaking process (Colville et al., 2012) happens to be on-going. Copies of relevant SD-related policies upon which the projects were premised was obtained and understudied. The emergent data were subsequently analyzed using a variant of the Qualitative Content Analysis (QCA). The themes were not predetermined but allowed to emerge from the data sets. The authors understood the concept of sustainability governance, ID systems, and success factors and deployed this

understanding in making sense of the data, hence culminating in the success factors identified in the subsequent section.

#### **4. Discussion of Findings**

In this section, the presentation and discussion of preliminary findings from the studied cases will ensue. However, the findings will not be structured on a case by case basis but rather along two main themes. These themes consist of the following: the level of Infrastructure Client Organization (ICO) satisfaction with the delivered asset and, the success factors for designing sustainability governance into ID systems.

##### *4.1 Level of ICO Satisfaction*

Client dissatisfaction with the delivered infrastructure asset has remained topical within the realm of construction project management and governance research (de Blois et al., 2011, Loosemore and Richard, 2015, Gan et al., 2015). Often, the project team is fixated on the attainment of project management success and not project success. This has often led to the incidence of projects which have met the success criteria of time, cost, and quality (according to the specifications whilst failing to support the actual objective that led to its commissioning in the first place). This challenge has been exacerbated with the increasing advocacy for ICOs to contribute towards the actualization of the sustainability agenda through their project development initiatives. Scholars agree that the operationalization of SD dimensions through projects remains a confusing territory (Banihashemi et al., 2017, Marcelino-Sádaba et al., 2015); especially the social SD aspects (Sierra et al., 2015, Herd-Smith and Fewings, 2008). The ICO representatives across the three case studies were asked if the projects being delivered/delivered had mandates for implementation of SD-related mandates during the project delivery lifecycle. All the relevant interviewees answered in the affirmative, citing instances of a modification of the pre-qualification documents and tender documents to cater to the achievement of such mandates. These mandates were mostly concerned with the engagement of local labour, use of labour-intensive approaches for construction, upskilling of the artisans on facets like bookkeeping and basic accounting practices. Also mentioned was the patronage of local suppliers and locally available goods, responsible sourcing, adoption of environmental-friendly activities during delivery, resource efficiency. This information is not new given the plethora of literature concerning targeted procurement, local content development, social value, etc. (Watermeyer, 2012, Hawkins and Wells, 2006). Although such mandates are replete in developing country and developed country contexts, they seem to align with socio-economic SD dimensions in the former, unlike in the latter where environmental SD dimension gained an upper hand until recently.

Upon this confirmation of the existence of such mandates besides the usual project success criteria of time, cost, quality, and functionality, the interviewer sought to determine the level of satisfaction experienced by the representatives of the ICOs as it concerned the ability of the ID system to achieve these SD mandates. Interviewees from the ICOs involved with Case 1 and 3 expressed a 'below average' degree of satisfaction whereas the representative from the ICO for Case 2 posted an above average score. The response obtained provided the platform for appraising the cases with the VIDM to engender the success factors for designing for

sustainability governance in ID systems. This is based on a proposition that ID systems which have been designed to facilitate effective sustainability governance will engender the implementation of SD-based mandates during delivery.

#### 4.2 Success Factors

The term ‘success factors’ has gained prominence in the project management and governance domain since the early works of Pinto and Slevin (Müller and Jugdev, 2012). These scholars attribute the salience of success factors to the increasing need for project managers and relevant stakeholders to manage, appraise and report on project performance. In this regard, project success factors and project success criteria have been utilized. Although, a clear distinction between success factors and success criteria is provided therein, this study is concerned with the former, which has been described as comprising of a set of distinct elements which when influenced, are able to increase the likelihood of the project/activity being successful (Müller and Jugdev, 2012:758). In this study, success factors for designing sustainability governance into ID systems will comprise of various elements or set of elements which are likely to increase the likelihood of engendering successful incorporation of SD ethos into the governance apparatus of the delivery system. Expectedly, such successful incorporation will lead to the implementation of sustainability initiatives during the procurement and delivery phases of the infrastructure project.

Table 4: Some success factors identified

Success Factor Identified	Description
Presence of Six Subsystems of the VIDM	This success factor is associated with the tenets of the VIDM’s base model- the Viable Systems Model. According to the model’s underpinning philosophy, for organizations to achieve and maintain viability which in this case is likened to ability to incorporate sustainability ethos into various facets of the project delivery process, the six subsystems previously mentioned in Table 1 must be present in the ID system. This implies that the roles and responsibilities of the various contracting parties within the ID system and their expected contribution to sustainability is clearly spelt out in a succinct manner.
Principle of Recursivity within the subsystems of the VIDM	According to the principle of recursivity, each of these subsystems should possess the entire six systems to support attenuation and provide robustness to the ID system. In the case where the VIDM is being deployed to engender sustainability governance, all contracting parties should be able to show evidence of the responsibilities associated with the six subsystems in each of these organizations.
Definition of ID-system’s purpose	Due to the need to avoid confusion and strategy/policy disjuncture, it is imperative that the purpose of the ID-system is properly highlighted to all participants. The purpose of a system is described as what the system has set out to achieve.
Presence of properly articulated communication pathways within ID system	Communication is critical to the success of ID systems especially in fostering effective sustainability governance. Taking cognizance of the difficulty in measuring certain aspects of SD, effective communication and consensus among contracting parties concerning how to exchange information in a succinct and unambiguous manner is imperative.



Whereas a plethora of success factors have been identified thus far as is evident from Table 4, this study will, for brevity sake, provide discussions on some of these factors.

#### *4.3 Presence of the six subsystems of the VIDM*

Based on the tenets of philosophies underpinning the VIDM, the Viable Systems Model (VSM) and theory of systems viability, the presence of six subsystems within the VIDM/VSM remains mandatory for the attainment of viability. Viability in this regard refers to a critical organizational (temporary multi-organizational) attribute which infers an organization's ability to go beyond merely performing its functions but posting successful performance (Adham et al., 2012). Based on the law of requisite variety, systems viability allows a system to remain viable, delivering on its purpose whilst maintaining its identity without undue influence from its environment (Schwaninger, 2012). Suffice to state that the organizations are only able to implement the set objectives (like SD ethos) optimally if they can attain and maintain viability.

Proponents of systems viability opine that the presence of the subsystems mentioned in Table 1 within an organization will enable that organization to become viable. Transposed to the ID system project environment, these subsystems will comprise of policy/strategy documents, organizations, departments and individuals carrying out the functions allocated to these subsystems and the composition of their internal structures in the case of organizations and departments. Based on the need to ensure compliance with the principle of recursivity- see Schwaninger (Schwaninger, 2006), an understanding of the internal structures of the implementing organizations and/or department, as well as the regulatory agencies, become imperative.

In the cases understudied, the interviewer had to conceptualize the entire ID system from the perspectives expressed by the interviewees within each case. Sequel to this, the authors reviewed the emergent vignette to decipher the responsibilities of the various organizations operating within the ID-system and the extant interorganizational interfaces for instances of collaboration or otherwise. Following the review, it was observed that Cases 1 and 3 did not possess a comprehensive representation of the required subsystems. For instance, in case 3, there was no policy/strategy document or the resolution of the board of the institution stipulating the SD-related mandates as expected deliverables. In Case 1, whereas the mandates were explicitly stated in government policy, the implementing agency prioritized cost-cutting measures through upholding lowest and most responsive tenders against the value proposition of empowering the local economy. However, in Case 2, the mandates were clearly spelled out during the procurement process and monitored during the project implementation process proper. In designing for sustainability governance in ID systems, there is need to ensure that the various organizations are made to be aware of their responsibilities concerning the implementation of any SD-related mandates that are expected of the ID system. This will allow for transparency in the manner that trade-offs are arrived at between various facets of the mandate. In addition, interviewees were unanimous on the need to allow for early engagement and involvement of the project stakeholders. They argued that this will provide a platform for the development of a common ontology as it concerns the significance of the project in the implementation of the SD-related mandate. When this is done properly, an ID system stands a

better chance of delivering on SD-related benefits through the instrumentality of effective sustainability governance.

#### *4.4 Definition of ID-system's purpose through established communication channels*

A proper definition of the ID system's purpose is imperative at the early stages. Scholars opine that a system's purpose is what it does/ or what it was set up to do (Schwaninger 2012). Impliedly, ICOs should clearly articulate the purpose of the ID system at the commencement of the project. Such an articulation will assist relevant stakeholders to understand what facets to prioritize above others. Across the three cases examined, the purpose of the ID system was not clearly articulated. When the interviewer sought to establish the perception of the interviewees concerning the purpose of their ID systems, all interviewees identified the delivery of the physical asset on time, to the approved budget and in accordance with the specifications as the purpose of their respective ID systems. No mention as made of the SD-related deliverables by any of the interviewees. This implies that the communication of the policy/strategy initiatives which necessitated the project's commissioning was not performed in an appropriate manner. As such, relevant parties will be concerned with the delivery of the project to the previously mentioned parameters. Also, they will be unwilling to make concessions for the incorporation of any SD deliverables which they opine may lead to cost escalation. Therefore, the establishment of clear and concise communication pathways within the ID system remains another salient success factor for designing for effective sustainability governance in Infrastructure projects.

### **5. Conclusion**

This study sought to identify the success factors required for the design and development of workable sustainability governance frameworks within infrastructure delivery systems. It is quite clear that ICOs are fostering the inclusion of SD deliverables through the projects being undertaken but lack the proper monitoring and control of achieving the desired outcomes. Evidence from the case studies highlight the continuous business as usual approach adopted by project team members of measuring success of projects based on time, cost and quality and pay diminutive attention to SD as a parameter for project success. Moreover, several ICOs do not have the complete subsystems mentioned in Table 1 to assist them with the design and implementation of proper governance strategies (labelled as sustainability governance) for achieving SD mandates during infrastructure project delivery, hence the VIDM is proposed as a veritable framework for enabling this within the ID system. As such, the VIDM is relied upon in this study as a platform for appraising the approaches taken in facilitating sustainability governance in ID systems whilst identifying the success factors for engendering such governance approaches.

Success factors identified from the study's findings includes the need for a detailed definition of the ID system's purpose at beginning of the project with the involvement of all project stakeholders. Secondly, early involvement of the project stakeholders proved to be imperative for project success as mentioned by respondents. SD as an outcome is proving to be complicated for project teams to implement due to the continuous iron triangle of project management success factors being the only measurement of performance of ID systems. A

proper policy/strategy on SD is imperative to communicate with all stakeholders of the ID systems in order to cascade that to implementation phases of the projects. Clear and concise communication pathway is key to achieving SD deliverables on ID systems. The study is still on-going. Thus far, the findings from this study fail to meet the analytic generalization requirements. This should be considered a limitation of the present study. It is expected that findings from this study will contribute to the emerging discourse on sustainability governance of ID systems to facilitate improved delivery of SD mandates during the delivery phases.

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# Exploring Organizational Suitability of Construction Companies for Developing Project Management Organizational Competence

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## Abstract:

This paper aims to describe a research carried out to explore if construction companies have the organizational suitability required to be successful in the pathway to achieve an appropriate project management (PM) organizational competence and to keep it in the long-range. To achieve this purpose, an organizational suitability evaluation system was developed, which was applied to five Chilean companies. The evaluation system was constructed using knowledge available in the literature that allowed the identification of the main organizational driving factors for developing the PM organizational competence. The main result of this research was the finding that these companies recognize the importance of achieving a high level of PM organizational competence, but as the same time, they have not yet developed policies, standards and mechanisms to formalize and standardize PM processes at an organizational and project level. In fact, it was found that in these companies each project manager manages their projects based on their own knowledge and experience and little on systematized PM knowledge and practices of their companies because the latter are almost not extant. Results obtained in this research allow to know the strengths, weaknesses and opportunities for improvement of the driving factors for the development of the PM organizational competence and are a necessary input for construction companies to improve these driving factors and finally, bring them to achieve and sustain a high degree of PM maturity.

*Keywords: project management; competencies; construction companies; organizational suitability, evaluation*

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## 1. Introduction

The construction industry is one of the main engines that drives the development and progress of the Chilean society (Peralta & Serpell, 1991). Most construction projects, as well as each of their execution stages, have a relatively short life, making them to run against time. In addition, they have large budgets, multiple stakeholders and a high degree of uncertainty that makes them difficult to plan, implement and manage effectively (Patanakul et al., 2016). Nowadays, the development of projects is increasingly complex, creating great challenges for companies, which are very difficult to cope for those who have a low level of PM competences (KPMG, 2011). The PM is the application of knowledge, skills, tools and techniques to project activities to meet the requirements of the project (PMI, 2017). It also refers to the planning, supervision and control of all aspects of the project, and the motivation of all those involved in it to achieve the objectives in time, cost, quality and specified requirements (PDA Project Management, 2007). In a rapidly changing environment with various problems and initiatives,

effective PM can support the achievement of the project and organization objectives, and also provide greater assurance to stakeholders that resources are managed effectively (Tasmanian Government, 2011). Additionally, studies have reported savings in costs of the order of 10 to 20% of the total cost of the project due to a formal and standardized application of PM by organizations (Jenner, 2010). Therefore, it is very important that organizations are mature from the point of view of PM, that is, that they have the ability to manage their projects based on defined and standardized processes, and also have a staff that has the adequate skills to manage the projects (Axelos, 2016).

Due to the gap found in existing maturity models and the importance of soft factors in the formal use of PM, a different perspective is proposed in this paper in the sense that, instead of evaluating the maturity of the application of PM, the interest should focalize on identifying the main driving factors for the development of the PM organizational competence, that is, those factors that are necessary to create, facilitate and promote the formal and standardized development of the PM organizational competence in organizations. Having identified these factors, an evaluation system was built that allows knowing the weaknesses, strengths and opportunities for improvement of each of these driving factors and, finally, to know if the organization has the environment and the organizational conditions to develop PM maturity in an effective way, a concept defined in this research as the degree of organizational suitability for the development of PM maturity. Then, the research questions that was addressed by this research are:

- How can organizational suitability for developing PM organizational competence be measured?
- What is the organizational suitability for developing PM organizational competence of a group of Chilean construction companies?

This evaluation system was applied to five Chilean companies belonging to the construction industry. The results obtained in this paper allow help to understand if Chilean construction companies have the cultural environment and the organizational conditions to develop the PM organizational competence in a formal and standardized mode.

## **2. Background**

### *2.1 Project Management (PM)*

Organizations that are forced to compete for the development of projects see a specific value in the use of PM, which consists of a competitive differentiator that benefits the relationship with customers and ensures the repetition of the business. (Crawford & Helm, 2009). However, the construction industry has been lagged behind in the formal and standardized use of PM practices compared to other industries. There are several reasons for this delay in the formal adoption of PM. One is that construction companies usually develop short-term projects, generating difficulties in the implementation of complex PM strategies (Chinowsky & Meredith, 2000). In addition, the predominance of small and medium-sized enterprises directed by the owner contributes also to the slow adoption of PM practices, since it has been shown that these companies are less aware of the importance of a standardized use

of such practices, and have a greater concern for short-term management (Jennings & Beaver, 1997). Other barriers that affect the formal and standardized adoption of PM are linked to the way in which senior management implements these initiatives. According to KPMG (2011), for organizations to get a value through the use of PM practices and tools, they must determine their strategy and culture, the nature of their projects and the objectives that they seek to achieve before determining the type of PM practices or tools to be implemented.

Therefore, today it is very important for organizations to be mature from the point of view of the PM, meaning that they should have the ability to manage their projects based on well-defined and standardized processes, and also have a staff with the right skills to manage projects (Axelos, 2016).

## *2.2 PM maturity*

From the point of view of PM, maturity is the degree to which an organization has developed explicit and consistent PM processes, which are documented, managed, measured, controlled and continuously improved (Chrissis et al., 2009). Due to the need to know the PM maturity by organizations, many researchers and institutions linked to PM have developed different models to evaluate this maturity (Backlund, Chronéer, & Sundqvist, 2014a).

In general, the existing models measure the maturity of PM through a stepped scale. This measurement is based on subjective evaluations of the use of the different knowledge areas of the PM, and finally, a maturity level is obtained for each PM knowledge area (Young et al., 2014). Therefore, results of the PM maturity level assessment are an input to create a strategic plan to move the PM forward in an organization (Crawford, 2006).

Despite the benefits that the use of the maturity models can offer to measure the PM maturity level of an organization, various studies have identified shortcomings and gaps that the existing maturity models have. Jugdev & Thomas (2002) state that PM maturity models usually focus on the processes or knowledge areas of the PM and ignore some intangible aspects of organizations such as culture, leadership and other soft factors that are important for the formal and standardized use of PM. While Young et al. (2014) state that existing PM maturity models have certain limitations, which have to do with maturity models that are incomplete, lacking soft attributes such as cultural and organizational aspects, which are an important part in the formal use of PM. On the other hand, Cooke-Davies & Arzymanow (2003) state that the PM maturity of an organization depends not only on the maturity of the PM processes and knowledge areas, but it is also influenced by other soft factors that are intrinsically found in organizations such as culture, executive leadership and the skills that the staff possess. Therefore, the assumption of maturity models is that an improvement in the PM processes maturity will produce an improvement in the PM maturity that an organization has, which is not necessarily true, since it has not yet been empirically tested (Milosevic & Patanakul, 2005).

According to the evidence provided by the studies mentioned above, it can be observed that the existence and development of soft factors such as culture, leadership, communication, teamwork and the executive support that exists in an organization is essential for a formal and standardized development of the PM organizational competence in organizations. Therefore,



organizations must first focus on the development of such soft factors, before thinking on developing the PM processes and knowledge areas to achieve PM maturity and to hold it in the long range.

### *2.3 Organizational suitability for the development of PM organizational competence*

According to RAE (2017) the suitability is defined as the situation of meeting the necessary conditions to perform a function. Suitability can also be defined as the aptitude, willingness or ability that something or someone has for a certain purpose. In this paper the degree of organizational suitability for the application of PM is defined as the degree at which an organization has the cultural environment and the organizational conditions to develop the PM organizational competence and apply it in a formal and standardize mode. Unlike the PM maturity level, which refers to the maturity of the different processes and knowledge areas of PM, the organizational suitability for the development of PM has to do with the existence and state of different soft factors, such as leadership, teamwork, culture, among others; factors that finally are the basis for organizations to develop the PM organizational competence in a formal and standardized mode. If these factors do not exist or are deficient, the PM organizational competence is not achieved fully, and its application becomes inadequate.

## **3. Research methodology**

To answer the research questions of this work, the research was divided into two stages: 1) the creation of an evaluation system to measure the organizational suitability for the development of the PM organizational competence, and 2) the application of the evaluation system to five Chilean construction companies to obtain the required data.

### *3.1 The evaluation system to measure the organizational suitability for the development of the PM organizational competence*

The evaluation system that was created during this research is composed by three main elements:

1. The driving factors for the development of the PM organizational competence.
2. A model for evaluation.
3. An evaluation methodology and its measurement instruments.

#### a) Driving factors for the development of the PM organizational competence

The first step was to carry out a literature review, with the objective of identifying and understanding the various factors that are considered important to facilitate and promote the development of the PM competence. From this review, a total of 78 factors were obtained, which were denominated as driving sub-factors.

In order to reduce the 78 sub-factors to a reasonable number, one of the quality management tools called affinity diagrams or affinity analysis was used. Using this tool, a first iteration was carried out, in which the 78 driving sub-factors were reduced to 44. With this number of factors, a second iteration was carried out in a collaborative workshop made up of four people with recognize expertise in this topic. This was done to include the point of view

of people outside the research and thus to ensure a greater objectivity in this way. Because of this iteration, factors were reduced from 44 to 25 driving sub-factors. Then, a third iteration was done where the opinion of a group of five professionals belonging to a Chilean construction company was consulted by means of a survey asking if they agreed or not with the driving sub-factors identified above. From this opinion, the driving sub-factors were finally reduced from 25 to 20.

Then, these 20 driving sub-factors were grouped into six major driving factors for the development of the PM organizational competence as follows:

1. Organizational environment and culture,
2. Knowledge,
3. Leadership and teamwork,
4. Organization,
5. Processes, and
6. Communication.

b) The model for evaluating the organizational suitability for the development of the PM organizational competence

The model is composed of two elements: driving factors and sub-driving factors and a scale of the degree of organizational suitability for the development of the PM organizational competence, which is used for measuring the sub-factors and producing the resulting level of organizational suitability. The scale of the degree of organizational suitability contains four levels of organizational suitability.

c) Evaluation methodology and its measurement instrument

For the data collection a questionnaire was used. The creation of a questionnaire must take care of the reliability, content validity, and construct validity of it, because this ensures that the results obtained are representative of the reality studied (Hernández Sampieri et al., 2006). Therefore, the content validity and reliability of the questionnaire was obtained by means of conducting a questionnaire pilot test, which consisted in the launching of the questionnaire draft to five professionals belonging to one of the construction companies that were part of the study. The objective of the pilot questionnaire was to test the content validity of the questionnaire by checking its format, receiving feedback on the quality and quantity of the variables that the questionnaire intended to measure and of the questionnaire's application time.

### *3.2 Data collection procedure*

The procedure began with the establishment of two groups, A and B, both composed by the same number of people and with similar positions in each of the five organizations. First, the questionnaire was sent to group A, and therefore, the results of the degree of organizational suitability of the driving factors for the development of the PM competence was obtained. These results were sent to group B through another questionnaire, which includes the answers of group A, but also the other three degrees of organizational readiness remaining of each one of the driving factors in the case that they do not agree with any answer of group A. After responses

of group A and B were obtained, a comparison of responses was made for each of the driving factors that were evaluated through a non-parametric hypothesis test, and thus determine whether the responses of both groups were statistically equal.

In the case that group A and B responses were statistically equal, the results obtained by group A of the degree of organizational suitability of the driving factors are obtained directly. If it is the case that responses are not statistically equal for some evaluated factor, the results of group A and B are averaged and thus the result of the degree of organizational readiness for that evaluated driving factor is obtained. The procedure described above is shown in Figure 1.

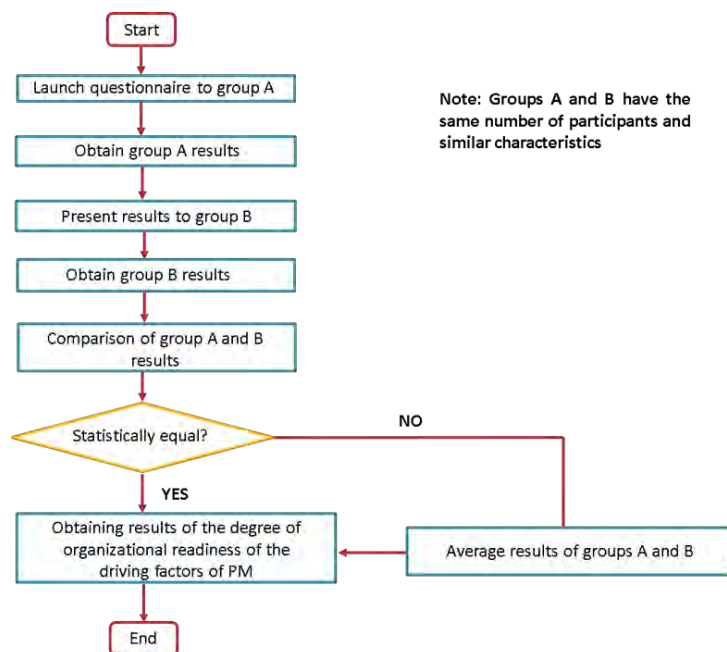


Figure 1. The data collection procedure

### 3.3 Case studies

The study was carried out with four construction companies and one mining and maintenance services company that also works in the construction sector, in which professionals from different levels of the organizations participated. In order to know the level of organizational suitability of companies for the development of the PM organizational competence, a questionnaire was launched, taking a sample of people involved in the development of projects, specifically: chief executive officers, senior managers, project managers, field professionals and technical office staff. This approach was used to obtain results considering all the viewpoints of companies and avoid biases. Table 1 shows the characteristics of the companies studied and the number of people who participated in the questionnaire.

Table 1: Characteristics of the companies studied and number of participants.

Company	Size	Industry	Number of participants
A	Large	Construction	24
B	Large	Mining and maintenance services	26
C	Large	Construction	11
D	Large	Construction	19
E	Large	Construction	15

Note: According to the Chilean Internal Revenue Service, a company is considered large if it has annual sales exceeding US\$ 4,000,000.

#### 4. Results and analysis

The main results of the research are shown below, and have been divided into the following aspects:

- The evaluation system of the organizational suitability for the development of the PM organizational competence and its components.
- The application of the evaluation system of organizational suitability to each case study.

##### *4.1 The evaluation system of organizational suitability for the development of the PM organizational competence*

###### a) Driving factors for the development of the PM organizational competence

As a result of this stage of the research, six major driving factors were obtained, composed of twenty sub-driving factors. It was considered that all factors and sub-factors have the same weight, since according to the literature review all are fundamental for the development of the PM organizational competence and there is no relative importance between them. Figure 2 shows the six driving factors for the development of PM with their respective sub-driving factors.

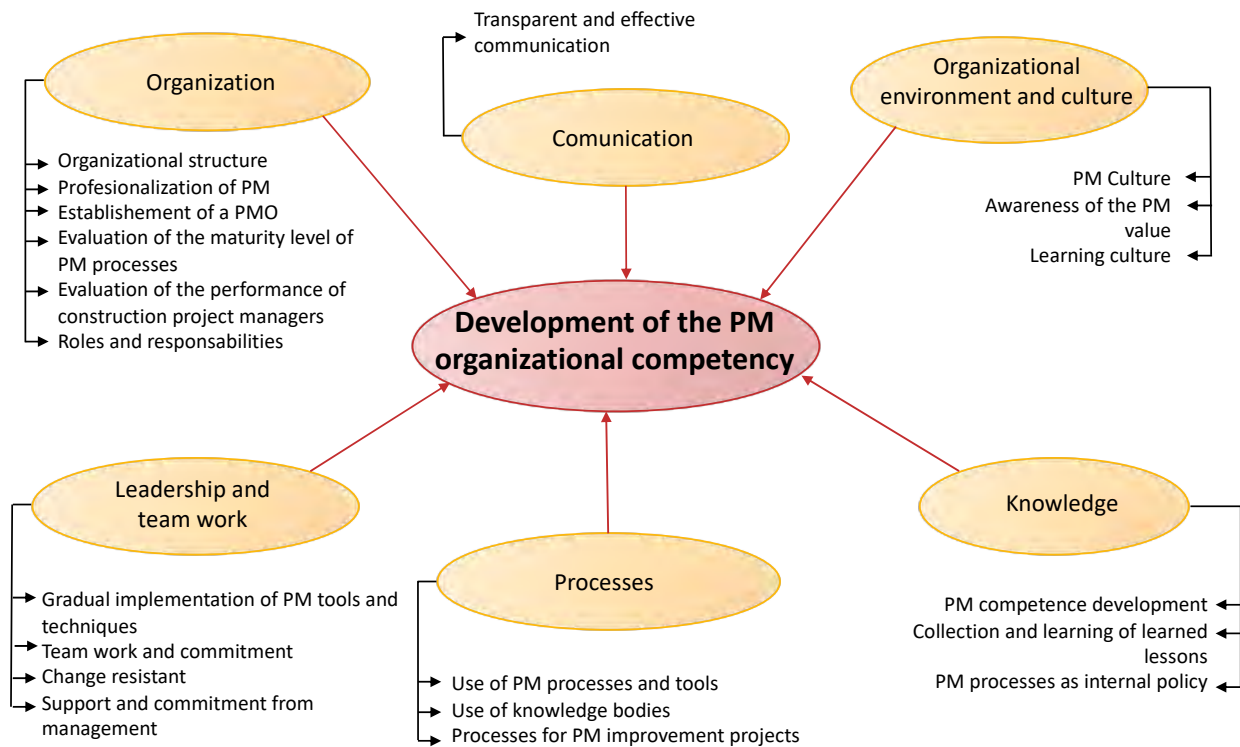


Figure 2: Driving factors and sub-factors for the development of the PM organizational competence

It is important to mention that these factors have a strong soft component, that is, they are strongly related with culture, leadership, executive commitment, and organizational structure, among others. In addition, the development of these factors is fundamental since according to the literature they are considered as necessary for the development of the PM organizational competence in organizations.

#### b) Organizational suitability evaluation model

The scale used has 4 levels of organizational suitability for the development of the PM organizational competence, as follows:

**Level 1. Elementary condition:** The organization is not aware of the importance of the development of the PM organizational competence because most of the personnel does not know the basic concepts, the importance, and benefits of PM in project development. Management does not support the development of PM, which depends on individual efforts and capabilities, since there are neither PM standards nor formal processes in the organization.

**Level 2. Recognized condition:** The organization provides partial support towards the development of the PM organizational competence. There is a recognition of the importance of the development of PM by managers, but there is not a behavior that clearly supports the development of PM. Basic efforts to develop PM processes and methodologies exist, but there is not a standardized and mandatory application to all projects.

**Level 3. Committed condition:** Most of the organization is committed towards the development of the PM organizational competence, particularly management that is willing to assign resources to carry it out. The organization is willing to work in the development of

policies and procedures that promote a standardization and systematization of PM. In addition, there is an attitude towards a mandatory, systematic, and standardized application of PM in most projects.

Level 4. *Enhanced condition*: People at all levels of the organization are commitment toward the development of the PM organizational competence, where senior management proactively seeks to improve existing PM processes and methodologies to bring them to a condition that the PM competence becomes a competitive factor. In addition, there is a conviction that PM should be applied consistently.

The objective of the model is to measure the degree of organizational suitability of each of the driving factors through the organizational suitability scale. As a result of this measurement, a first diagnosis of the degree of organizational suitability of the driving factors is obtained, and thus, the organization can know its weaknesses and strengths with respect to these factors. Later, the organization can execute improvement projects to promote the further development of these factors following the structure of the model, which provides an effective path of improvement to reach the highest degree of organizational suitability for developing the PM organizational competence.

#### c) Evaluation methodology and its measurement instruments

The main characteristic of the questionnaire is that it is composed of the description of different situations or scenarios that these factors can assume, according to the evaluation scale shown above. The general characteristics of the questionnaire are presented in more detail in table 2.

Table 2: Characteristics of the questionnaire.

Characteristic	Questionnaire design
Variables to be measured	Driving factors and sub-factors for the development of the PM organizational competence
Format of the questionnaire items	Description of situations or scenarios represented by a scale from 1 to 4, which represents the 4 levels of organizational suitability for each sub-factor
How to respond	Of the 4 scenarios proposed for each sub-driving factor, the respondent chooses the one that best represents his/her company
Final evaluation	a) Driving factor score: it is calculated as the average of the driving factor scores of all questionnaires. In each questionnaire, the driving factor score corresponds to the average of the scores of their respective driving sub-factors b) Organization's score: it is calculated as the average of the scores of the 6 driving factors.

#### 4.1 Case studies

This section presents the main results obtained from the application of the evaluation system to the five construction companies.

a) Degree of organizational suitability of the driving factors for the development of the PM organizational competence

Table 3 shows the Cronbach's alpha coefficients of the evaluations of the degree of organizational suitability of each company, obtained through the statistical software SPSS. According to the coefficients obtained, it can be concluded that the results of the evaluation for the five companies have a high degree of reliability, since the coefficients are above 0.70 (Bojórquez et al., 2013).

Table 3: Cronbach's alpha coefficient by company.

Company	A	B	C	D	E
Cronbach's alpha coefficient	0.815	0.931	0.893	0.912	0.843

Table 4 shows the results obtained from the five companies studied in the research. The six driving factors for the development of the PM organizational competence have an average level of organizational suitability between two and three. It means that for the six driving factors companies recognize the importance of these factors in the formal development of PM, because they have carried out improvement actions to enhance their degree of organizational suitability.

The issue here is that these companies have not yet managed to pass to the committed condition level of these factors, since adequate mechanisms have not yet been created such as policies, procedures and a system. This is what is preventing companies from advancing to a high degree of organizational suitability that will allow them an effective development of the PM organizational competence and to sustain this competence along time.

Table 4: Degree of organizational suitability of the driving factors for the development of the PM organizational competence

Driving factors for the application of PM	Company A	Company B	Company C	Company D	Company E
Organizational environment and culture	2.72	2.46	2.62	2.77	2.75
Knowledge	2.36	2.42	2.23	2.17	2.87
Leadership and teamwork	2.71	2.69	2.76	2.60	2.83
Organization	2.65	2.50	2.19	2.48	2.13
Processes	2.56	2.29	2.24	2.44	2.47
Communication	2.29	2.15	2.00	2.30	2.20

Another reason that explains why the driving factors for the development of the PM organizational competence only achieve a recognized condition of organizational suitability (level 2) can be attributed to the characteristics and structure of the scale with which they were evaluated. For a driving factor to advance from a recognized condition level to a committed condition level of organizational suitability (move from degree 2 to 3), the company must have an attitude from management that promote this kind of behaviour.

b) Degree of organizational readiness of the companies studied for the application of PM

Table 5 shows the degree of organizational suitability for the development of the PM organizational competence of the five companies studied, which corresponds to the average of the scores of the six major driving factors.

Table 5: Degree of organizational readiness of the driving factors

Company	A	B	C	D	E
Level of organizational suitability for the development of PM organizational competence	2.55	2.42	2.34	2.46	2.54

According to the results it can be concluded that the five companies studied have a recognized condition level of organizational suitability (level 2), which means that the organizations provide a partial support towards the application of PM and also that executive managers recognize the importance of the formalization of PM. Additionally, there is an application of basic PM processes and methodologies, which do not have a standardized and mandatory application for all projects.

Also, an analysis of the variances (ANOVA) was carried out to find out if there are statistically significant differences in the degree of organizational suitability for the among companies. Specially to know if there are differences between the company B, which belongs to a category of maintenance and mining services, and the other construction companies. Table 6 shows the results of the ANOVA.

Table 32: ANOVA of results obtained in the five companies studied

ANOVA					
	Sum of squares	dof	Quadratic mean	F	Sig.
Between groups	0.542	4	0.136	1.230	0.303
Within groups	10.473	95	0.110		
Total	11.016	99			

Because the significance value obtained in the test is greater than 0.05, the null hypothesis is accepted (Vicéns et al., 2005), which states that there are no statistically significant differences in the degree of organizational suitability for the development of the PM organizational competences among the companies studied. Therefore, it can be concluded that the degree of organizational suitability is very similar for the five companies that participated in this study.

## 5. Conclusions

According to the results obtained in the study cases, it can be concluded that the five companies have a recognized condition level of organizational readiness (level 2) for the



development of the PM organization competence. This means that although the companies recognize the importance and value of project management, they do not consider it as a critical issue and are not willing to spend resources in this process. Then, companies do not have the conditions to develop PM and use it as a competitive leverage. This situation causes that each project manager of the organizations manages their projects based on his own knowledge and experience. Therefore, if companies want to reach a high degree of organizational suitability, they must work on improving the six major driving factors for the development of the PM organization competence to create the necessary conditions to travel the road to PM maturity with success and to sustain this maturity over time.

The evaluation of the degree of organizational suitability of these factors might help companies to act on the weakest factors. Companies can break the commitment barrier and reach a higher degree of organizational suitability for the development of the PM organization competence and for the application of PM. The similarity in the degree of organizational readiness for the driving factors of each company can be attributed to the characteristics and structure of the scale used to measure these factors and also that the relative high level obtained by each company may relate to the fact that in general, construction professionals are overly optimistic when they evaluate their companies.

On the other hand, the organizational readiness evaluation system shown in this paper can measure with reliability and validity the degree of organizational suitability of the driving factors for the application of PM, though it can be improved to produce a better discrimination in the answers. The evaluation system provides a contribution to Chilean construction companies or any other project-oriented company, since its application provides information on the weaknesses, strengths and opportunities for improvement of the driving factors.

Finally, this research generated a contribution to the existing knowledge related to PM. This evaluation system complements the PM maturity models existing in the literature, since these are oriented to measure the capability of organizations to apply the processes and knowledge areas of PM leaving aside soft factors such as culture, knowledge, communication, leadership, among other, which are fundamental for the development of the PM organization competence.

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# Technical Opinion Leaders in Facility Companies' Renewable Energy Projects

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## Abstract:

Sustainable energy projects represent a growing market for planned and current commercial buildings. New sustainable solutions for buildings gain better subsidies and simultaneously lower energy costs and reduced environmental footprint. The knowledge from such projects needs to be spread to accelerate the change from fossil to carbon-neutral energy production. As the cost of construction projects has increased significantly in recent years, new projects look for standards that lower their maintenance and accreditations that offer a lower interest rate. However, the process to adopt new energy projects and adjust these with standards requires numerous steps, which are not always progressive. This paper is built on a multi-study of recent energy construction projects in Sweden spanning workshops with managers, field studies, and a large survey. Given that no study has introduced a stepwise index of gestation activities for sustainable energy construction projects so far, we present a model of energy construction investments and project characteristics. The model presents sufficient conditions by introducing an index of various activities and its relationship perception, and need and use of energy solutions. Besides offering a step model, it elaborates the companies' activities when it comes to self-efficacy, intentions, how they promote renewable energy, and if they take the role as a technical opinion leader. The results show the dynamics of the steps, as well as how the activities interplay. The paper has several implications for theory and practice.

*Keywords: energy projects; project life cycle; project performance;*

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## 1. Introduction

Projects follow a stepwise process in which a former step is replaced by a new progressive step forward (Jaafari, 2001). We usually refer to the entire set of processes as the project lifecycle (Pinto et al., 1988) and actively promote certain targeted management practices for each cycle (Atkinson et al., 2006). Although projects are temporary in nature (Pesämaa et al., 2018), they tend to vary in complexity (Thomé et al., 2016) and time (Brookes et al., 2017). As time and complexity vary, path dependence makes projects conditioned to key competencies that take projects to completion (Liljenfeldt et al., 2017). Such key competencies hold practices that enable them to learn (Eriksson et al., 2017), use experience (Takey and de Carvalho, 2015) and share important knowledge with others (Abu Bakar et al., 2016). Given the importance of sustainability projects and their specific characteristics (Kivilä et al., 2017), diffusion knowledge (Hartmann and Dorée, 2015) and affecting others (see, for example, Miterev et al., 2017) become central in renewable energy projects.

Most construction projects are complex in nature, requiring coordination and use of specialized knowledge; furthermore, they call for key individuals that hold projects together (Pesämaa et al., 2018). Prospect theory (Ahiaga-Dagbui and Smith, 2014) assigns great responsibility to individuals who develop experiences and skills to reach decisions independently. It is also proven that the larger and more complex a project is, the more likely it is that individuals will rely on their experience rather than on rational facts (Altman, 2010). Furthermore, prospect theory documents other behaviors, such as individuals tending to focus on minor details when situations are complex (Altman, 2012). To this end, literature such as that on technological opinion leadership (Bruner and Kumar, 2007) assumes that certain individuals are more knowledgeable and successful in persuasion over others and influence certain behaviors. Yet, a competing literature, that on hidden champions, identifies projects that evolve successfully in silence and secrecy, and that tend to conceal or hide information (Voudouris et al., 2000). While some industries favor the dissemination of ideas, others may see less interest pursue ideas as the process is difficult.

An important observation from following this research project (from an interview with a representative for a Swedish wind power agency) is that carrying out new energy production projects (e.g., wind power plants) is estimated to take up to ten years from presenting a plan to first delivery. Most of the time, lagging issues are caused by government administration and financing before actually setting up and running the wind power plant (interview with a wind power company CEO). The rather time-consuming planning requires experience in conducting this type of project, as well as identifying the right people of whom to ask questions. A report confirms that most suppliers and staff in Swedish wind power projects are highly specialized and recruited abroad, and the cost of staff is approximately 10–15 percent of the total cost of a wind power project (Andersson, 2015). A Swedish project establishing the Markbygden wind farm confirmed that 52 percent of staff came from other countries and 48 percent were Swedish, of whom 42 percent were local (Andersson, 2015). The relatively time-consuming project administration and the fact that these projects are large in scope (one billion euros) also impose uncertainty on the project. Once the government authorizes the building, the step of supporting the project financially starts. Energy investment projects depend on the efficiency of the final production unit, the cost of building, the market price of electricity, and currency. Thus, the financial step may require a significant amount of planning and coordination, conditioned by authorized permissions and regulatory complexity. Finally, an energy project, like any project, demands that building and maintenance standards (including costs) be followed. Each of these steps involves multiple sub-steps which are not fully described in the current literature. In business research, one approach suggests that business start-ups can be explained by examining each step of the start-up (Davidsson and Honig, 2003). This process refers to each sub-step as an observable gestation activity (i.e., “incubation periods”). This literature assumes that each step may evolve either progressively or, in more uncertain circumstances, on an iterative basis. In the latter case, a step forward may also take the same project a step backwards.

We propose, based on a multi-study approach (Sutton and Rafaeli, 1988)..As no one to our knowledge has adopted such a multi-study approach focusing on various steps of the project, we believe it could fruitfully support more knowledge about the way new energy and construction projects evolve. Renewable energy projects come with added dimensions and

considerations of sustainability, as such projects need to consider sustainability issues throughout the different project stages. Otherwise, both the symbolic and economic benefits of the future green energy production can suffer (negatively) from the means to which the (positive) end was conducted. Given the importance of renewable projects when it comes to environmental challenges, a deeper understanding of their dynamics is needed. We therefore propose a three-step model. In addition to proposing the steps in an index, we also examine in what ways self-efficacy, renewable energy intentions, and technological opinion leadership affect each step in the project lifecycle.

## **2. Background: Renewable Energy Projects in Sweden**

The following section is based on workshops and field studies involving Swedish real estate companies, energy companies, and other actors identified as relevant to gain insights into the complexity of renewable energy projects.

In the European Union, Sweden has one of the more ambitious agendas when it comes to being carbon dioxide-neutral in 2045, which is reflected in the stated ambitions from both governmental agencies and companies. The Swedish energy system recognized early on the economic and ecological potential and benefits of fossil-free energy production, such as hydropower energy production on a broad scale, and, during recent years, strategic initiatives in large-scale wind power and photovoltaic (i.e., solar) power plants—renewable energy sources that requires high technical knowledge (Jenkins and Ekanayake, 2017)—have increased. While energy production has traditionally been an issue for large-scale power production plants, it has, through the introduction of renewable energy alternatives, become a strategic question for commercial real estate companies that can gain economic or differentiation benefits by investing in renewable energy. Examples span a Swedish real estate company that only offers its tenants wind power (by developing a large wind power park), as well as multiple other real estate companies that have installed solar panels on the roof and thereby reduced their energy dependency, as well as installing displays that show the commercial tenants the level of their (own) energy production.

One major Swedish renewable energy initiative is the construction of the biggest wind power plant facility in Europe, Markbygden, located in mid-northern Sweden near the city of Piteå. Once completed, an astonishing capacity of up to 12 TWh will be possible (equivalent to a nuclear plant). These investments support the overarching goal to replace fossil-based and atomic energy with renewable energy production. Regardless of scale, the planning, financing, and building and maintenance of renewable energy power plants are somewhat obliged to pay attention to sustainability-specific issues throughout the different project stages (e.g., materials, practices of sub-suppliers, etc.) to avoid being associated with environmentally negative issues. In this sense, the study of such projects contributes to a deepened general understanding of how issues of sustainability can impact the strategic and operational aspects of project lifecycles. In such projects, we have identified three steps; these are presented below.

## 2.1 *Step 1 – General conditions*

The first step, labeled general conditions, is to grasp the full potential technologies and regulations. Step 1 is associated with the company's strategy, but also basic technical requirements and regulations. The company must also investigate its conditions: the source of energy is dependent on the facilities and the land the company owns. It must also incorporate its organizational and managerial context (Atkin and Brooks, 2015). Solar power can often be an integrated part of the building, for example, while wind power needs to be located in the countryside. The technologies' efficiency also changes over time. Solar power panels have been made more efficient year after year, so the company that installs them will find itself left with 'old' equipment rather soon. Windmills has become higher and higher and hence more powerful throughout the years. While 80 meters was high some years ago, 120 meters is now not that high (according to technical specifications). Considering such technical aspects includes estimations, and when it comes to windmills, might also include a potential lease of land which needs to be specified and contracted. This first general conditions step also entails investigating the relevant laws and regulations. A public official at the Swedish Windpower Agency, responsible for wind investments in the northern region of Sweden, described the current licensing process and explained that "the time from the first contact to producing the first kWh is on average eight years." He further stressed that this was a step that held many contingencies which, from a company perspective, must be considered a high-risk part of renewable energy projects. The CEO of ManComp A had completed a larger renewable energy project and explained: "We bypassed the long process of getting required documents and certificates and bought two windmills in a large ongoing project." The sales manager at WindPower Ltd. explained that this long and challenging process was their main business idea: they created packages holding the examination, planning, calculations, and necessary documents that companies interested in renewable energy can buy, thereby speeding up the process from the initial idea to a running renewable energy installation. He described that the "permission process tends to 'grow' over time", but could grow through their experience and specialization.

Finally, Sweden and Norway have developed a joint energy certificate (Finjord et al., 2018) that allows new renewable energy producers—for example, a commercial real estate company—to sell their electricity over-production to the grid. Having insights into how these energy certificates worked was a necessary condition that all companies that had taken their first steps in the area of renewable energy displayed.

## 2.2 *Step 2 – Financial conditions*

Once the general requirements are fulfilled, the adopting company needs to assess the financial conditions. This second step has characteristics similar to the first, but the focus is now narrowed to financial effects. All business respondents had estimated both the investment cost and the running cost, as well as the potential income. The approach to the economic assessment varied. ManComp A's CEO described that the owners had a deep sustainability interest and that the focus was on "what the company does", but he also wanted to communicate this to a broader audience. Thus, renewable energy also, directly or indirectly, became an income driver beyond selling overproduction.

The financial step involves estimating future energy pricing and price models, available subsidies, and current and future taxes. As an example, the CEO at ManComp B had a windmill running for three years and concluded that “the energy prices have not been nice”—that is, there had been low energy prices since they got their windmill and the payback had taken a long time. Another respondent, a CTO at Real Estate Company X, concluded that “that the government offers subsidies one year, and then takes the money back through a new tax the next year.” This analysis also includes estimating the price and effect of technology. Thus, the second stage that assesses the financial conditions incorporated many dynamic variables, even if the scope was more specific than in the first stage.

### *2.3 Step 3 – Build and maintenance*

The building and maintenance stage has the main characteristics of traditional construction projects, where the initial idea is fulfilled and the company can gain access to the energy produced by the equipment. However, this may not be a straightforward task, given that companies that have not produced their own energy in the past may lack knowledge about potential suppliers and their quality, and do not have the required knowhow in-house. Thus, this is a stage for developing supplier relationships, hiring and training staff, and deciding if the energy plant should be owned, leased, or made available in some other way (Atkin and Brooks, 2015). The CTO at Real Estate Company A, as an example, highlighted that the latter question was critical for many companies that wanted solar power: his company advocated owning every installation that belonged to a building, while he knew many other companies who preferred leasing arrangements. The CTO at Real Estate Company B echoed this opinion: they wanted to be in control of all their installations. The building and maintenance stage is also where the company becomes more knowledgeable about renewable energy.

The final evidence of companies that had entered this last stage came from those who had started, and even more, those who had completed projects. Three interviewed companies had used renewable energy for years (ManComp A, ManComp B, and real Estate Company B), and none of these respondents bragged about it: it was instead, in a seemingly relaxed way, simply ‘how to do things’ from now on. When discussing the value of the renewable energy, besides reducing the need to purchase energy from others, the CEO at ManComp A explained that “we have not made any money from it, but it is a matter branding.”

### *2.4 Summarizing the Steps*

When summarizing the studied steps, it becomes evident that the focus and level of practical actions are shifting in characteristics and scope (see Figure 1 below). These steps are used in the upcoming hypothesis development, and they will later be an integral part of the developed index.



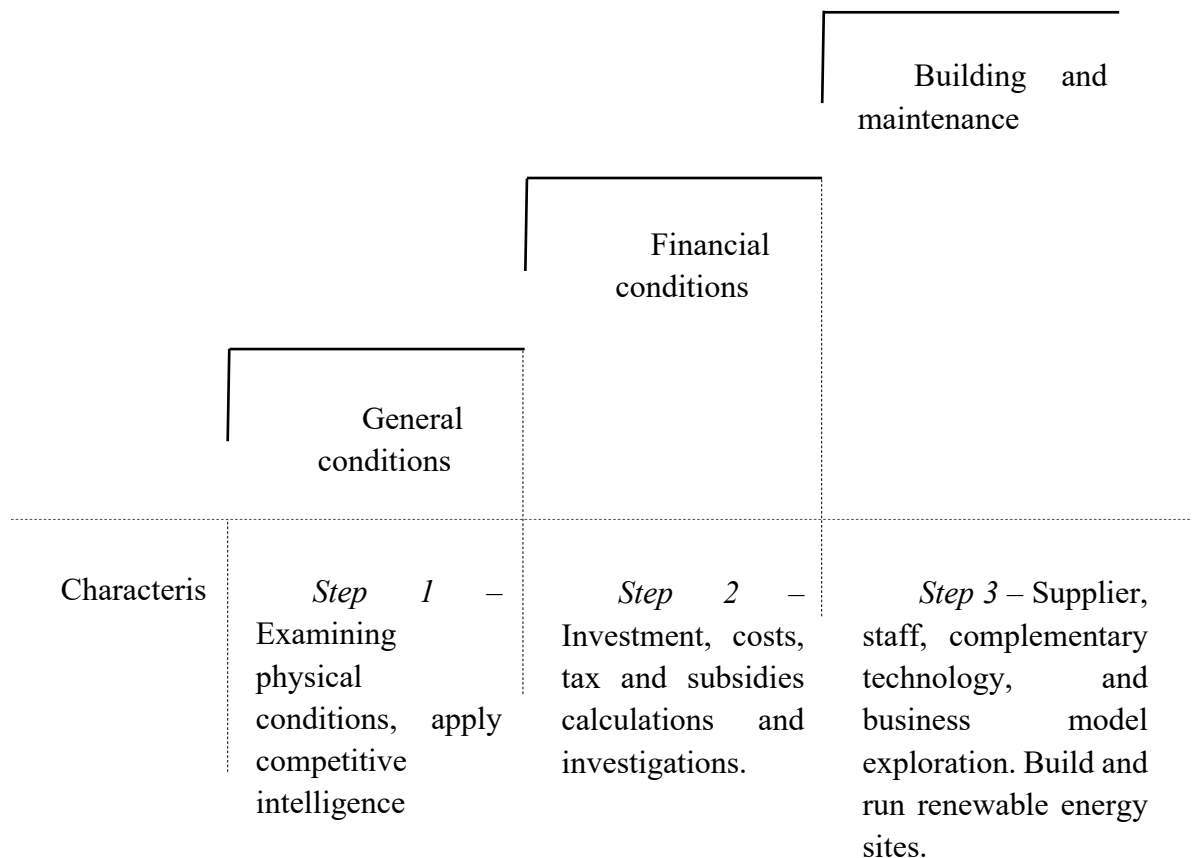


Figure 1. Renewable energy project steps

### 3. Theory and Hypotheses

Linking process to project success is common in project management (Mir and Pinnington, 2014). The process of a new sustainable energy project is conceptualized herein as a sequence of steps, which include a number of gestation activities (e.g., planning, raising finance, and building). It is further assumed that each activity involves a number of issues which, when solved, take the project to completion (Mir and Pinnington, 2014).

Process performance (Larsson et al., 2018) refers theoretically to a combination of routines, work procedures, administrative procedures, activities, capabilities, coordination, and skills leading to tangible outcomes (Eriksson et al., 2017). We can further assume that the more activities and the more skills involved in completing the outcome, the more complex the situation will be. However, the more complex the scope of the project, the more likely it is that managers will abandon routines and trust their past experience (Altman, 2010). Project controls may also require standards and add complexity instead of relieving uncertainty (Jun et al., 2011). Current research therefore suggests that feedback may support a reduction of uncertainty and increase the likelihood of preferred outcomes (Pesämaa et al., 2018). Working with and through technical opinion leaders and in collaborative projects is therefore considered central to complex projects. In addition, it is known that uncertainty dictates that many construction industries projects are controlled collaborative efforts (Pesämaa et al., 2018) pursued from one point).

### 3.1 *Self-efficacy*

Self-efficacy reflects the ability, qualification, and belief to independently solve emerging technical challenges. In psychology (Blomquist et al., 2016) the concept refers specifically to an individual's own judgment of his or her capabilities to perform given actions, as opposed to the judgments and evaluations of others regarding an individual's capability. Self-efficacy is herein defined as “belief in one's capability to mobilize the motivation, cognitive resources, and courses of action needed to meet given situational demands” (Wood and Bandura, 1989: 408). Self-efficacy has been applied as a means to explain different behaviors and is recognized as a person's ability to take on various roles (Strauss et al., 2009). For example, researchers have found evidence of a relationship between self-efficacy and an ability to support the success or failure of projects (Jani, 2011), task complexity (Wang et al., 2014), and drive financial issues of projects (Jani, 2011). However, no studies have been conducted to measure self-efficacy within the area of new energy technology and the various steps of a project to completion.

Self-efficacy can be seen as task-related activity (Wang et al., 2014). Self-efficacy as an intrinsic driver pushes tasks in a specific direction, albeit with the help of others. In this regard, self-efficacy supports judgment and confidence in one's own ability. Researchers have also noted that self-efficacy is conditioned by situations and complexity, such as pursuing specific projects. Therefore, we can expect:

H1a-c: Self-efficacy in energy projects have a relationship with (a) planning, (b) financing processes and (c) build and maintenance step in energy projects.

### 3.2 *Renewable energy intentions*

Renewable energy intention is here defined as the willingness to replace (use) past solutions with new available technology. An individual's behavior is essentially determined by his/her willingness to perform a specific task. We often measure things and sometimes without actually directing these measures. Yet any reporting is assumed to have a direction (Marques and Fuinhas, 2011). Furthermore, any controls such as feedback are assumed to control if the desired behavior matches the actions at hand. In management control literature, measures (i.e., controls) are detected to control a certain behavior. Research in project management suggests that intentions in general, and particularly renewable energy intention, may predict how projects evolve over time (Lee et al., 2016). Renewable energy intention is therefore used here as a key factor influencing the method and ability to plan an entire energy project. An individual's renewable energy intention, and particularly in the context of a project leader, plays an important role in arriving at various project decisions and adopting adequate technology. Thus, it can be assumed that:

H2a-c: Renewable energy intentions in projects have a relationship with (a) planning, (b) financing processes and (c) build and maintenance step in energy projects.

### 3.3 *Promoting renewable energy use*

Promoting renewable energy use reflects activities directed to customers, suppliers, and employees (Marques and Fuinhas, 2011). Empirical findings have documented the relationship

between financial activities and energy use (Painuly, 2001), intention to reduce consumption (Finn and Fitzpatrick, 2014), suppliers (Menanteau et al., 2003), and promotion of energy use. The concept of use is generally known in the project management literature as affecting behavior, particularly the selection of devices, routines, and facilitators (Lee et al., 2016). While much of the selection is predefined and path dependent, the promotion of renewable energy use supports controlled behavior. It is thus also assumed to control processes and entire project management lifecycles. Therefore:

H3a-c: Promoting renewable energy use is assumed to have a relationship with (a) planning, (b) financing processes and (c) build and maintenance step in energy projects.

### 3.4 *Technological opinion leadership*

Technological opinion leadership is important for renewable energy investment projects, as uncertainty can be reduced and creative ideas proposed to achieve progress in the project. Technological opinion leadership is represented by individuals that perceive themselves as opinion leaders in their social circles on the basis of their expertise, education, status, or income (Joe et al., 2016). The more complex a project is, the more uncertainty the project will pose, thus requiring persons or knowledge to reduce the uncertainty. This is one foundation of technological opinion leadership.

These individuals are often specialists and vocally strong, convincing others through their own selected products, behavior, knowledge, expertise, and arguments. In projects, an individual can sometimes take or be given a technological opinion leadership position. The individual is thus legitimated by others to pursue decisions based on their experience or knowledge. The position is assumed to be critical, as it also becomes easier for others to accept the same solutions.

The role of opinion leaders has been recognized as important, as they feed expected information to key decision-makers (Odusami et al., 2003), but they can also misuse the role by using interpersonal networks to pursue their own self-interest (Mwanthi et al., 2015; Pinkse and Groot, 2015). Generally, we know that the influential role played by opinion leaders also makes them seem more important than others (Locock et al., 2001). Therefore, the notion of the role of opinion leaders is also important as they are known to influence the adoption of routines in projects and further influence others to use these practices (Jansson et al., 2017). Hidden champions can be seen as the opposite to technological opinion leaders, as players that may be high achievers within an industry or a niche (Simon, 2009) but that are unknown and ‘flying under the radar’, where others may miss their expertise.

We know opinion leaders promote ideas on others (Singh, 2017) and affect purchasing behavior. The more complex, unknown, and innovative the product, the greater opinion leaders’ power over others’ decisions will be (Nisbet and Kotcher, 2009). Energy solutions are typically complex products that can be placed or misplaced socially (Singh, 2017), economically and politically (Wolsink, 2007a, 2007b). As such ideas are often costly, and positioning such decisions requires arguments, well developed plans, and a perception that the decision was

reached only after strong consideration. An opinion leader is an individual that can plant arguments and develop plans.

Lamm et al. (2015) suggest that opinion leaders are an efficient way of arriving at knowledge on how energy decisions are reached, as they already hold an influence over their sphere. While the influence of attitudes and use is well documented, few have clearly addressed the role of opinion leaders in the likelihood of targeted energy solutions for commercial buildings.

This paper therefore builds on the established theory of planned behavior framework in combination with energy replacement and acceptance. In line with the previous discussion, we expect that:

H4a-c: Technological opinion leadership have a relationship with (a) planning, (b) financing processes and (c) build and maintenance step in energy projects.

## 4. Method

### 4.1 Study Design

The empirical multi-study comprises four complementary stages (as two subsequent studies) of data collection to provide a well-founded understanding (Creswell and Plano Clark, 2011) of the issues related to the complexity of renewable energy production projects, in terms of current and future incentives regarding the need, development, and utilization of renewable energy. The study was thereby structured in four steps.

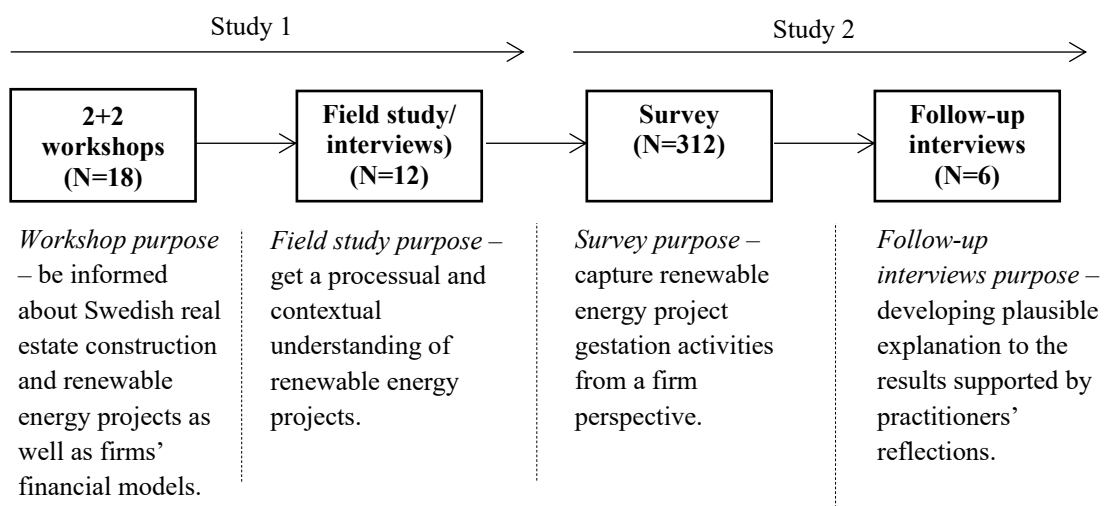


Figure 2. Study design

The project was initiated through four workshops with leading Swedish real estate companies. This phase held two workshops each with (i) firms that mainly had commercial office tenants that mainly had offices, stores, and restaurants; and (ii) firms and public real estate organizations that mainly had public tenants like schools, museums, and hospitals. The workshops involved 16 landlords and two non governmental organizations (NGO). The overall purpose of the workshops was to establish a contextual understanding of the ‘if’, ‘how’, and ‘why’ of companies within this sector (being central energy users) regarding energy and its

related sustainability challenges. The workshops mainly involved environmental managers and CTOs that were engaged as reflective practitioners (Schön, 1982). Real estate companies in Sweden have increasingly shown an interest in becoming either self-sufficient in energy use (e.g., installing solar panels on their buildings) or investing in wind power plants to reduce their environmental footprint. Hence, the participants offered valuable insights into both the underlying aspects associated with the potential benefits of renewable energy usage, and the challenges of initiating and implementing energy production projects.

The second step was field studies, where we visited sites under development in parallel with interviewing central actors participating in renewable energy projects (from small-scale solar power installments in facilities to large-scale projects like Markbygden, the development of Northern Europe's largest wind power plant). To get a deeper insight into the process and challenges of renewable energy projects, we widened the scope by interviewing three real estate firms, four manufacturing firms with substantial self-owned buildings, a public official that supported renewable energy projects, one large energy company, and a renewable energy consultant. This phase held 12 interviews that lasted an average of two hours.

The third step was a survey. The results from the interviews were used partly to understand the phases of renewable energy projects and partly to develop an index of the critical activities in renewable energy projects. The development and structure of the questionnaire is further presented below.

Finally, we re-established contact with some of the respondents to clarify the results through interviews. This phase also included offering a brief report of the results to the questionnaire respondents. This gave rise to further comments and clarifications.

#### 4.2 *Sample - survey*

The survey was developed based on the prior interviews. Once tested and revised, it was sent out to 1400 organizations and 312 surveys were returned. All surveys were representing organizations involved in energy-related investments, who completed the questionnaire. To ensure a relevant sample, we reached out to organizations that have applied for support and subsidies from the Swedish Energy Agency, a government agency focused on the supply and use of energy, not least the transition to a sustainable society. Of the respondents, 234 (75%) represented an organization that has received support for an investment in renewable energy, and thus had relevant experience for the study. A further 78 respondents (25%) represented organizations owning and maintaining buildings and facilities and were in a role involving hands-on decisions regarding energy-related investments. Given the informed and strategic sampling, this study relies on a unique data set. The respondents represent both supply and demand of energy. Approximately 20 percent of the companies were in the utilities sector, 43 percent in real estate, and 10 percent in farming. Of the represented organizations, 41 percent were single entities, whereas the rest were part of a company group. The organizations are located all over Sweden. Of the respondents, 61 percent were in a managerial position, thus having good insight into the strategic and decision-making perspective. The remaining 39 percent had roles within facilities management and maintenance, sustainability, or

administration. Almost 36 percent of the respondents were owners of the company, 77 percent were men, almost 58 percent were aged 50 or above, and 61 percent had university education.

Table 1. Descriptive information of the sample

Company profile	Mean (S.D)
Age	34 (26)
Employees	114 (366)
Turnover (kSEK)	743 634 (1 807 625)
R&D spending last 5 years (kSEK)	5 968 (104 849)
Patents, book value (kSEK)	1195 (12 851)
Goodwill, book value (kSEK)	8302 (87 663)
Total assets (MSEK)	5378 (15 151)
Intangible as % of total assets	0.5 (3.4)

### 4.3 Questionnaire

The operationalization of the step model is made up of selected items that reflect the steps in renewable energy project development into full project completion. The results of this survey study are reported below. The individual answers (yes/no) were coded 1 for yes and 0 for a no. We knew from the interviews that each step could be extremely long term, and simply planning and pursuing permission to build may take up to five or six years. Yet, to follow up on each activity, energy investors fulfilled and accounted such activity as a sub-step referred to as index. These activities measure each of the three steps as follows.

*Step 1:* General conditions define a conditional step which involves planning, administration, and contacts with regulatory and governmental authorities. To capture a proxy of this process, we refer to four items: (1) a clearly stated plan for investing in renewable energy; (2) the conditions in current properties and facilities; (3) good knowledge of electricity certificates; and (4) how laws and regulations for energy work.

*Step 2:* Financial conditions define a rather complex step which involves not only calculation and budgeting, but also developing knowledge on available subsidies and tax effects for future operations. To capture a proxy of this process, we refer to six items: (1) the possibility of selling excess electricity to the open electricity market; (2) a capital budget for renewable energy; (3) tax effects (e.g., electricity grid charge); (4) project pay-off; (5) financing opportunities; and (6) knowledge of which grants and subsidies can be applied for.

*Step 3:* Building and maintenance conditions define exit processes and thus everything from the exit of the project to recruiting, training, and finding suppliers and finding maintenance solutions of batteries or leasing a solution. To capture a proxy of this process, we refer to six sub-steps: (1) inventing possible suppliers of key resources; (2) recruiting specialized or trained staff; (3) starting one or more projects; (4) completing one or more projects; (5) considering battery solutions and energy storage; and (6) considering leasing instead of operating the property independently.

We then developed and tested scales for the operationalization of our behavioral concepts, as follows.

*Self-efficacy* in projects is operationalized by following Blomquist et al. (2016) and proposing project measures that reflect capabilities, confidence, ability, and qualifications which are task related. We used a seven-point Likert scale ranging from ‘strongly disagree’ to ‘strongly agree’. A multi-item questionnaire with five items was used to measure self-efficacy by computing a composite score (see Table 5).

*Renewable energy intentions* are defined as intentions and behaviors directed toward renewable options (Rai and Beck, 2015). We used three items to capture such intentions (see Table 5). We asked the respondents to assess each item on a seven-point Likert scale.

*Promoting renewable energy* use was developed following Marques and Fuinhas (2011). We operationalized the scale so that it reflected activities directed to customers, suppliers, and employees. We used a multi-item scale with three variables. We asked the respondents to assess the items on a seven-point Likert scale.

*Technological opinion leadership* is here defined as an individual’s value over others’ opinions on professional matters, and reflects an operationalization inspired by Sadik-Rozsnyai (2016). We operationalized the scale so that it reflected various activities measuring influence over others. We used a multi-item scale with five variables. We asked the respondents to assess the items on a seven-point Likert scale.

## 5. Results

The results section presents the findings of the study by first introducing the descriptive statistics of each step (see Tables 2–4). The individuals’ answers (yes/no) were coded 1 for yes and 0 for no. Frequencies for each rated sub-step and how all the steps were formed are reported in Tables 2–4 below.

Table 2: Step 1 – General conditions

When it comes to renewable energy, we have... Y/N	Yes	No
Index1: a clearly stated plan for investing in renewable energy	216	95
Index2: examined the conditions in current properties, land and facilities	272	39
Index3: good knowledge of electricity certificates	219	92
Index4: investigated laws and regulations	239	72

Table 3: Step 2 – Financial conditions

When it comes to renewable energy, we have... Y/N	Yes	No
Index5: investigated the possibility of selling (selling) excess electricity	235	76
Index6: made cost and income analysis of our renewable energy investment	252	59
Index7: examined tax effects	213	98
Index8: calculated payback time	270	41
Index9: examined financial opportunities for our investment	206	105
Index10: knowledge of which subsidies can be applied for	265	46

Table 4: Step 3 – Build and maintenance

When it comes to renewable energy, we have... Y/N	Yes	No
Index11: investigated possible suppliers	214	97
Index12: specially recruited and trained staff	229	82
Index13: started one or more projects	262	49
Index14: completed one or more projects	243	68
Index15: considered battery solutions and energy storage	135	176
Index16: considered leasing instead and running these in-house	254	57

The subsequent reporting of predictors as theorized and with corresponding operationalizations are presented in Table 5. Each measure is based on multi-item measures, and we note that every proposed measure meets the criteria for reliability (Table 5). We report a reliability coefficient Cronbach's alpha which exceed the recommended 0.70 (Nunnally and Bernstein, 1994: 264–265).

Table 5: Measurement properties

Measurements	Min	Max	Mean	S.D
Self Efficacy total (alpha=.85)				
SE1: I am confident I can solve problems and challenges myself.	1	7	3,89	1,58
SE2: I'm not afraid to say what I know and what works.	1	7	5,12	1,44
SE3: I take the time needed to perform the task.	1	7	4,94	1,38
SE4: Not difficult for me to get help through my contact network.	1	7	5,31	1,39
SE5: I trust myself for having done similar tasks before.	1	7	4,61	1,60
Self Efficacy total	1	7	4,77	1,18
Renewable Energy Intentions (alpha=.92)				
REI1: always choose the better energy solution.	1	7	5,07	1,68
REI 2: always drives issues that can provide energy improvements.	1	7	5,42	1,53
REI 3: always puts a lot of effort into energy efficiency.	1	7	5,21	1,53
Renewable Energy Intentions total	1	7	5,24	1,47
Promoting Renewable Energy Use (alpha=.75)				
PREU1: Expect our customers to do our utmost to adapt used renewable alternatives.	1	7	4,64	1,66
PREU2: We demand that our suppliers use renewable alternatives.	1	7	4,39	1,78
PREU3: We encourage our employees to learn more about renewable alternatives.	1	7	5,09	1,57
Promoting Renewable Energy Use total	1	7	4,71	1,37
Technological Opinion Leadership (alpha=.91)				
ToL1: I like to introduce new energy solutions to my friends.	1	7	5,24	1,61
ToL2: I am often expected to help others with information about energy solutions	1	7	4,91	1,74
ToL3: Others often ask me for information about energy solutions.	1	7	4,83	1,67
ToL4: It would be embarrassing if I can't help with an answer to energy products.	1	7	3,98	1,76
ToL5: People see me as an important source of information to new energy solutions.	1	7	4,36	1,76
Technological Opinion Leadership total	1	7	4,66	1,46
Step1 General Conditions	0	4	3,04	1,16
Step2 Financial Conditions	0	6	4,63	1,77
Step3 Build and maintenance	0	6	3,19	1,55



Tables 6–8 present statistics findings from our regression. Note that models are presented stepwise in order to separate potential mediation as a variable enters a model. In total, we present nine models. The first model (Table 6) presents the step 1 model, and we can explain roughly 15–21.40 percent of the variance in step 1 by our four predictors. Turning to the individual hypotheses, we find that self-efficacy (H1a), as expected, has a significant and substantial effect on general conditions (step 1) (Table 6, Model 3a:  $\beta=0.34$ ;  $p<0.001$ ). Furthermore, and as expected, renewable energy intentions (H2a) affect general conditions (step 1) substantially, and this is also statistically significant (Table 6, Model 3a:  $\beta=0.23$ ;  $p<0.001$ ). In addition, promoting renewable energy use (H3a) has a positive substantial and statistically significant effect on general conditions (step 1) (Table 6, Model 3a:  $\beta=0.20$ ;  $p<0.001$ ). We can also document a relationship between technological opinion leadership and step 1, although this relationship is negative (Table 6, Model 3a:  $\beta= -0.23$ ;  $p<0.001$ ).

Table 6: Regression Step 1 – General conditions

	Model 1a	Model 2a	Model 3a
Hypotheses	$\beta$	$\beta$	$\beta$
H1a: Self-Efficacy	0.25***	0.23***	0.34***
H2a: Renewable Energy Intentions	0.22***	0.17**	0.23***
H3a: Promoting Renewable Energy Use		0.19***	0.20***
H4a: Technological opinion leadership			-0.24***
R <sup>2</sup>	15.53%	18.81%	22.41%
Adj. R <sup>2</sup>	14.99%	18.02%	21.40%

\*\*\* $p<0.001$ ; \*\* $p<0.01$ ; \* $p<0.05$

The next model (Table 7) presents the step 2 model, and we can explain roughly 14.90–20.25 percent of the variance of financial conditions (step 2) by our four predictors. Turning to the individual hypotheses, we find that self-efficacy (H1b), as expected, has a significant and substantial effect on financial conditions (step 2) (Table 7, Model 3b:  $\beta=0.40$ ;  $p<0.001$ ). Furthermore, and as expected, renewable energy intentions (H2b) affect financial conditions (step 2) substantially; this is also statistically significant (Table 7, Model 3b:  $\beta=0.25$ ;  $p<0.001$ ). However, we find no support that promoting renewable energy use (H3b) affects financial conditions, as there is no significant relationship (Table 7, Model 3b:  $\beta=0.06$ ;  $p>0.05$ ). We can also document a relationship between technological opinion leadership and step 2, although this relationship is again negative (Table 7, Model 3b:  $\beta= -0.30$ ;  $p<0.001$ ).

Table 7: Regression Step 2 – Financial conditions

	Model 1b	Model 2b	Model 3b
Hypotheses	$\beta$	$\beta$	$\beta$
H1b: Self-Efficacy	0.27***	0.26***	0.40***
H2b: Renewable Energy Intentions	0.19**	0.18**	0.25***
H3b: Promoting Renewable Energy Use		0.05 <sup>N.S</sup>	0.06 <sup>N.S</sup>
H4b: Technological opinion leadership			-0.30***
R <sup>2</sup>	15.49%	15.69%	21.27%
Adj. R <sup>2</sup>	14.94%	14.86%	20.25%

\*\*\*p<0.001; \*\*p<0.01; \*p<0.05; <sup>N.S</sup> = Non significant

The next model (Table 8) presents the step 3 model, and we can explain roughly 12.58–16.60 percent of the variance of building and maintenance (step 3) by our four predictors. Turning to the individual hypotheses, we find that self-efficacy (H1c), as expected, has a significant and substantial effect on building and maintenance (step 3) (Table 8, Model 3c:  $\beta=0.37$ ;  $p<0.001$ ). Furthermore, and as expected, renewable energy intentions (H2c) affect building and maintenance (step 3) (Table 8, Model 3c:  $\beta=0.14$ ;  $p<0.05$ ). However, we find no support that promoting renewable energy use (H3b) affects building and maintenance, as there is no significant relationship (Table 8, Model 3c:  $\beta=0.15$ ;  $p>0.01$ ). We can also document a relationship between technological opinion leadership and building and maintenance (step 3), although this relationship is again negative (Table 8, Model 3c:  $\beta= -0.21$ ;  $p<0.01$ ).

Table 8: Regression Step 3 – Build and maintenance

	Model 1c	Model 2c	Model 3c
Hypotheses	$\beta$	$\beta$	$\beta$
H1c: Self-Efficacy	0.29***	0.27***	0.37***
H2c: Renewable Energy Intentions	0.12*	0.09 <sup>N.S</sup>	0.14*
H3c: Promoting Renewable Energy Use		0.14*	0.15**
H4c: Technological opinion leadership			-0.21**
R <sup>2</sup>	13,14%	14,90%	17,68%
Adj. R <sup>2</sup>	12,58%	14,07%	16,60%

\*\*\*p<0.001; \*\*p<0.01; \*p<0.05; <sup>N.S</sup> = Non significant

## 6. Discussion

This paper examines renewable energy projects through a three-step model, the commitment and activity in these steps being related to the investor's attitude and behavior. The results show positive effects of self-efficacy and renewable energy intentions, which means that an intention and belief in one's own ability drives action and commitment in all steps of the renewable energy project.

Promoting renewable energy use is positively related to steps 1 and 3, but not step 2. Technological opinion leadership is negatively related to all steps. This indicates that the knowledgeable and influential persons might not be the ones that pursue renewable energy projects to their completion. Such findings may also support the hidden champions literature (Voudouris et al., 2000) and question the role of technological opinion leadership (Bruner and Kumar, 2007). Specifically, our results indicate that the role of technical opinion leaders is indeed important (i.e., mean values are substantial), but that these self-reported scores generate a negative association with each step. This means that greater values are associated with less likelihood of completing a project and, conversely, lower values reflect more experience in each step of completing a project. In practice, this means some Technological opinion leaders may take a more advisory and supporting role than others, while others are clearly targeting action. We suggest that deep knowledge could hinder action, as too many factors and considerations complicate a decision. Companies that are driving renewable energy projects might, instead, be promoted by simplifying means, such as government subsidies. This negative effect is an interesting finding, where the role of technical opinion leaders is discovered in the context of the three other drivers. On its own, technical opinion leadership does not correlate with steps 1 and 2, and positively correlates with step 3 (Spearman's  $\rho = .124$ ,  $p = 0.29$ ). The negative effect of technical opinion leaders on renewable energy projects thus implies full mediation effects, which is supported by previous theory (Bruner and Kumar, 2007). To follow up on mediation, an analysis was made with step-wise regression (models a–c). This shows the mediating effect of technical opinion leaders, which strengthens the positive effects of the other factors when included in the third model. This further adds to the complex importance of technical opinion leaders and that some of the mechanisms cannot be developed in isolation when developing renewable energy projects. Technical opinion leaders are an important hindering factor to contrast the endogenous driving forces.

Financial conditions (step 2) differ as these are strongly driven by the two dimensions related to the investor's own confidence in pursuing such decisions and renewable energy intentions. The financial process documented in our project is complex and requiring in both interviews and survey.

The follow-up interviews also revealed that companies that have carried out some renewable energy projects normalize their activities—i.e., it is nothing to talk about. Instead, activities are 'taken for granted'. Future studies could examine if companies' engagement in renewable energy has a lifecycle, where new actors that have not carried out projects potentially act as technical opinion leaders, whilst experienced firms focus on getting the job done (i.e., self-efficacy).

## **7. Conclusion**

This paper is a first attempt to document and theoretically suggest gestation activities in renewable energy project management. Firstly, our paper clarifies the concrete steps that companies take to reach completion, and we suggest predictors that may explain this process. Secondly, we investigated the characteristics of real estate companies engaged in such projects and we documented a surprisingly negative relationship between key technological opinion

leaders at each step of the project process. We also found support for many of the suggested predictors.

This study is a first attempt to clarify how a deregulated and changing energy market has resulted in new forms of project. Renewable energy projects are vital to meet environmental challenges, but our study indicates that the engaged project leaders (technical opinion leaders) unfortunately do not support such a notion. Further studies are needed to clarify this negative relationship between project completion and inspiring others.

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## **Appendix**

### *Self-Efficacy (Cronbach's alpha=.85)*

When it comes to renewable energy I would say..,

SE1: I am confident I can solve problems and challenges myself.

SE2: I'm not afraid to say what I know and what works.

SE3: I take the time needed to perform the task.

SE4: Not difficult for me to get help through my contact network.

SE5: I trust myself for having done similar tasks before.

Self Efficacy total

### *Renewable Energy Intentions*

Even though it means big sacrifices in time and money, I would say that I ..,

REI1: always choose the better energy solution.

REI2: always drives issues that can provide energy improvements.

REI3: always puts a lot of effort into energy efficiency.

### *Promoting Renewable Energy Use*

When it comes to renewable energy I would say..,

PREU1: Expect our customers to do our utmost to adapt used renewable alternatives.

PREU2: We demand that our suppliers use renewable alternatives.

PREU3: We encourage our employees to learn more about renewable alternatives.

### *Technological Opinion Leadership*

When it comes to renewable energy I would say..,

ToL1: I like to introduce new energy solutions to my friends.

ToL2: I am often expected to help others with information about energy solutions

ToL3: Others often ask me for information about products that relate to energy and energy solutions.

ToL4: If someone asks where to find some specialty products for energy. it would be embarrassing if I can't help with an answer.

ToL5: I would say that people see me as an important source of information when it comes to new energy solutions.

Technological Opinion Leadership total



### Step 1: General conditions

When it comes to renewable energy we have..

Index1: A clearly stated plan for investing in renewable energy

Index2: examined the conditions in current properties. land and facilities

Index3: good knowledge of electricity certificates

Index4: investigated laws and regulations

### Step 2: Financial conditions

When it comes to renewable energy we have..

Index5: investigated the possibility of selling (selling) excess electricity

Index6: made cost and income analysis of our renewable energy investment

Index7: examined tax effects

Index8: calculated payback time

Index9: examined financial opportunities for our investment

Index10: knowledge of which subsidies can be applied for

### Step 3: Build and maintenance

When it comes to renewable energy we have..

Index11: invented possible suppliers

Index12: specially recruited and trained staff

Index13: started one or more projects

Index14: completed one or more projects

Index15: Considered battery solutions and energy storage

Index26: Considered leasing instead and running these inhouse

# Low-Energy Building Feasibility Analysis - A Business Case

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## Abstract:

This paper compares the feasibility of constructing a building using standard technology (materials and systems) and building by applying the low energy building principles. On the one hand, the construction sector is one of the largest environmental polluters and on the other hand, it is experiencing growth so there is a need for low energy construction to reduce the adverse environmental impacts. In this paper, two building types for the same building have been analyzed. The first type is insulated according to the minimum technical requirements under the conditions of the current regulation. Natural gas is used as a heating energy source and cooling is done via an air conditioner (electricity). For the second type, building materials and heating / cooling system were changed. For both building types construction costs and annual energy consumption were calculated. Based on the investment costs and the planned realized revenues, an economic and financial analysis was made as a basis for the evaluation of the investment project. The estimate shows that despite of the higher initial costs by using low energy building principles, significant savings are achieved in total energy consumption at the stage of building use, for an investor but also for the end-user.

*Keywords: feasibility study, low-energy building, sustainable construction, energy, NPV, IRR*

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## 1. Introduction

The construction sector is one of the largest environmental pollutants whose activities consume a large amount of natural resources and generate the big share of global waste. The construction and use of buildings in 2017 consumed 36% of global energy and emitted almost 40% of carbon dioxide (Global Alliance for Buildings and Constructions, 2018). As the construction sector is recovering after a decade of economic crisis, increase in energy consumption and carbon dioxide emissions can be expected. As an alternative to reduce the negative environmental impact of construction sector recently low energy construction is being used. As the construction sector is one of the largest pollutants every positive change can contribute to sustainability and environmental protection. In addition to the contribution to socio-economic benefits, with the development of new technologies for sustainable construction, new jobs will be created. Although initially expensive, low energy construction is reflected in rational consumption of energy, which contributes to saving resources over the life span of the property. As the society is increasingly aware of the impact of climate change, different laws and regulations have been adopted over the last two decades to ensure optimal use of resources.

Croatia has adopted a number of laws and regulations related to the sustainable development including the Energy Development Strategy of the Republic of Croatia (NN, 2009) for the period until 2020, which aims to build a balanced relationship between safety of energy supply, competitiveness and environmental protection. Currently, a new Energy Development Strategy for Republic of Croatia until 2030 is under development. Despite enacted laws and incentive measures to co-finance sustainable construction and use of renewable sources in Croatia, awareness of the need for environmental protection is still insufficiently developed. The reason for this is probably the lack of education of the population, so usually only the construction costs are considered. Nevertheless, Croatia has great potential for the development of a low energy house market.

This paper compares the profitability of two building types. The first type analyzes the a life cycle costs of for the residential building constructed considering only minimal requirements for thermal insulation in accordance with the current regulations in the Republic of Croatia. The second type analyzes the a life cycle costs for the equivalent low energy residential building.

The paper presents the comparison of the cost-effectiveness of the investment between a residential building with minimal contemporary thermal insulation and low energy building construction considering both the investor and the end user. For this purpose technical and technological analysis was made. To determine the construction costs, boll of quantities for both building types was made and the energy consumption budget was assessed, using "KI Expert Plus" software. Based on the obtained data, an economic and financial analysis was made for both building types with different initial costs and expected revenues, and finally an estimate was obtained based on two dynamic methods – NPV and IRR.

## 2. Project description

For the analysis the building is going to be built on 204 m<sup>2</sup> of land. The building is designed as a residential building with two duplex apartments with gardens and garages. Figure 1. presents a visualization of the proposed investment.



Figure 1. Conceptual visualization of the investment project

The allowed building shape according to the city spatial planning documents is an individual residential unit with a maximum of three stories, of which the third story is shaped

like an attic or an indented floor (Zavod za prostorno uređenje Grada Zagreba, 2017). Based on the size of the building plot and the level of spatial consolidation, the building is classified as an attached building. Total net usable area of the building is 244,64 m<sup>2</sup>.

#### *Building type 1 – construction with traditional building technologies and methods*

For the building in question, a foundation slab was chosen as the most appropriate. On the excavated and compacted soil, a thin layer of concrete is poured. On top of it, horizontal hydro insulation is placed, followed by the 40 cm thick foundation slab.

Thermal insulation is in the form of extruded polystyrene (XPS) in two layers, placed on the foundation slab and underneath polyethylene vapor-proof membrane. Depending on the room, the final layer will be either parquet or ceramic tiles, placed on the concrete glaze. External walls will be made with 25 cm thick masonry brick, upon which the façade system consisting of 10 cm thick expanded polystyrene (EPS) will be placed. Double glazed insulative PVC windows will be installed. Ceiling structure will be 20 cm thick reinforced concrete slab, while the roof structure will be a flat non-walkable inverse roof with a 4% slope. Inverse roofs have thermal insulation above the hydro insulation. The layers of the roof are as follows: reinforced concrete slab, sloped concrete layer, hydro insulation, thermal insulation (XPS), geotextile fabric, and pebbles.

Total construction costs were approximated based on the planned quantities and current prices on the market calculated by an online calculator (Troskovnik.net, 2019). The recapitulation of the works by types is shown in Table 1.

Table 1. Calculation of construction costs – *building type 1*

<b>TYPE OF WORKS</b>	<b>COST</b>
Construction and craft works	797,720.00 kn
Electrical works	81,885.00 kn
Plumbing and sewage works	22,375.00 kn
HVAC works	130,260.00 kn
<b>TOTAL:</b>	<b>1,032,240.00 kn</b>

Costs of specialist works were also added to the construction works. Here costs for electrical, plumbing and sewage works include all materials and works needed. As for HVAC works, the price includes the planned central heating via natural gas, pipes, radiators and the boiler for central heating, while cooling is planned through individual air conditioning units.

#### *Building type 2 – construction with low energy building technologies and methods*

Croatian low energy building council defines low energy building as a universal holistic approach to designing, constructing, maintaining, using, managing, and refurbishing buildings based on the principle of sustainability (Croatian Green Building Council, 2019). Low energy buildings are those which are built in order to reduce consumption of all energy-generating products while not changing the working and living conditions in the building. Buildings built according to the low energy principle also have lower CO<sub>2</sub> emissions.

For the considered building, the low energy construction will be achieved through the change in the materials of the outer façade, ceiling and roof structures, windows and by installing a heat pump and floor heating. The foundation slab remains the same; only one extra layer of thermal insulation will be added. Instead of brick masonry walls, 30 cm thick Ytong blocks will be used. On the intersections of the walls, vertical reinforcements will be made with Ytong U-shaped elements in which the steel reinforcements are placed and filled with concrete. For internal walls 10 cm thick Ytong wall panels are used. The Ytong blocks as building envelope do not need additional thermal insulation. The façade will be finished with grout, while the interior walls will be troweled.

Ceiling and roof structures will be constructed using prefabricated Ytong slab system, whose primary benefits include high thermal insulation properties, vapor permeability, and high resistance to fire and earthquakes. On the topmost structure the sloped concrete layer will be poured, upon which two layers of thermal insulation and a layer of hydro insulation will be placed.

Windows on a building let the heat from the sun into the building but also cause heat losses, sometimes even ten times larger than through walls. The coefficient of heat loss through windows and balcony doors needs to be smaller than  $U=1,80 \text{ W/m}^2\text{K}$ . In the object in question, windows with PVC frames and triple Low-E glass sheets will be installed.

Heat pumps are efficient heating systems which take the heat from the environment and distribute it throughout the building. The advantage of this technology is in the fact that around 75% of the thermal energy is gathered from the environment, which reduces the heating costs and CO<sub>2</sub> emissions. For this building, an air-water heat pump system is planned, which has both heating and cooling capabilities. The work costs recapitulation is shown in table 2.

Table 2. Calculation of construction costs – *building type 2*

<b>TYPE OF WORKS</b>	<b>COST</b>
Construction and craft works	882,862.00 kn
Electrical works	81,885.00 kn
Plumbing and sewage works	22,375.00 kn
HVAC works	277,770.00 kn
<b>TOTAL:</b>	<b>1,264,892.00 kn</b>

### 2.1 Consumption of raw materials and energy

The basic difference between regular and sustainable buildings is in energy efficiency, specifically, the yearly consumption of heat per square meter. The consumption depends on building geometry, materials used for the construction, and on heating and cooling systems used.

For both building types maximum consumption will be limited to 40 to 70 kWh/m<sup>2</sup> per year. For the building type 2, those numbers will be smaller, which will have impact on initial costs. To calculate the energy consumption for both building types „KI Expert Plus“ software

was used. The software is in line with the Technical ordinance on the rational use of energy and heat loss prevention in buildings (NN, 2015), Algorithm for calculating the energy needed for heating and cooling buildings (Soldo et al., 2017) and the Ordinance on energy audit of the building and energy certification (NN, 2017).

Based on the entered information on building elements and materials' heat transfer coefficients, defined as energy loss per second per one square meter of elements surface at a temperature difference of 1 K, were calculated. The values of the U coefficient are shown in Table 3. It should be noted that both variants satisfy the requirements set by the technical ordinance (NN, 2015).

Table 3. Heat transfer coefficients

Building element	Type 1 U (W/m <sup>2</sup> K)	Type 2 U (W/m <sup>2</sup> K)	Maximum acceptable value (U <sub>max</sub> )
External walls	0.29	0.26	0.30
External wall facing the garage	0.30	0.26	0.30
Ceilings between heated areas	0.50	0.32	0.60
Floor slab	0.34	0.15	0.40
Roof	0.19	0.17	0.25

Calculated heat losses for the building type 1 are 52.904,12 kWh, whereas for for building type 2 these are 45.745,67 kWh. These heat losses include transmission losses, ventilation losses, and inefficiencies of the heating system. Besides heat losses, the building has heat gains from people, lighting, appliances, and from the insolation which are 25.761,97 kWh for the building type 1 and 18.975,65 hWh for the type 2.

Annual requirement for thermal energy ( $Q_{H,nd}$ ) and annual required energy for cooling ( $Q_{C,nd}$ ) are calculated values of energy needed to maintain the designed temperature inside the building during both heating and cooling periods through one year (NN, 2015). Although the geometry of both building types are the same, the calculated energy requirements,  $Q_{H,nd}$  and  $Q_{C,nd}$  (shown in Table 4.), are different. This is due to the differences in surface weights of the buildings. In building type 1, when considering the weight of materials used in construction the calculated surface weight equals 428.37 kg/m<sup>2</sup> whereby the building is considered a heavy structure. Surface weight of building type 2 is 232.89 kg/m<sup>2</sup>, classifying it as a light structure.

Table 4. Annual thermal energy requirements

Building type 1	Building type 2
$Q_{H,nd} = 9,714.96$ [kWh/a]	$Q_{H,nd} = 9,005.79$ [kWh/a]
$Q''_{H,nd} = 49.82$ [kWh/m <sup>2</sup> a]	$Q''_{H,nd} = 46.19$ [kWh/m <sup>2</sup> a]
$Q_{C,nd} = 9,425.29$ [kWh/a]	$Q_{C,nd} = 6,293.10$ [kWh/a]
$E_{del} = 32,218.14$ [kWh/a]	$E_{del} = 4,196.37$ [kWh/a]
$E''_{del} = 165.23$ [kWh/m <sup>2</sup> a]	$E''_{del} = 21.52$ [kWh/m <sup>2</sup> a]
$E_{prim} = 45,062.31$ [kWh/a]	$E_{prim} = 6,772.94$ [kWh/a]
$E''_{prim} = 231.10$ [kWh/m <sup>2</sup> a]	$E''_{prim} = 34.73$ [kWh/m <sup>2</sup> a]

For the financial analysis of thermomechanical systems, delivered energy  $E_{del}$  is used. It is the amount of energy delivered to the consumer to satisfy the requirements for heating, cooling, ventilation, warm water preparation, lighting, etc. The amount of spent energy is displayed on the meter and is paid to the distributor. For research purposes here the energy used for heating, cooling, ventilation, and warm water preparation is considered since consumption through other sources depends on the human behavior and cannot be accurately calculated. Thus  $E_{del}$  for building type 1 is 32.218,14 kWh/a, whereas building type 2 consumes 4.196,37 kWh/a.

Yearly consumption is calculated by multiplying the delivered energy with a primary energy factor, depending on the energy source. Building type 1 requires 20,173.66 kn for heating, cooling, ventilation, and warm water preparation (Table 5.). Unit prices shown in the table are current market prices for natural gas and electricity.

**Table 5. Energy consumption and price of the energy sources – building type 1**

Energy source	$E_{del}$ (kWh)	Annual consumption	Unit of measure	Unit price [kn]	Total price [kn]
Natural gas	13,367.57	1,377.25	m <sup>3</sup>	2.61	3,773.67 kn
Electrical energy	18,850.57	18,850.57	kWh	0.87	16,400.00 kn
<b>Total</b>	<b>32,218.14</b>	<b>20,227.82</b>			<b>20,173.66 kn</b>

Applying low energy building principles and using renewable energy sources yields significant financial benefits. Heat pump uses electricity to heat and cool the building, therefore not requiring natural gas. Total cost for the energy sources for building type 2 is 3,650.84 kn (Table 6.) which is 16,552.82 kn less per year than for the building type 1. The difference between variants is evident through the quantity of delivered energy as building type 2 uses 67.54% of the total required energy which is attained through renewable energy sources.

**Table 6. Energy consumption and price of the energy sources – building type 2**

Energy source	$E_{del}$ (kWh)	Annual consumption	Unit of measure	Unit price [kn]	Total price [kn]
Electrical energy	4,196.37	4,196.37	kWh	0.87	3,650.84 kn
<b>Total</b>	<b>4,196.37</b>	<b>4,196.37</b>			<b>3,650.84 kn</b>

Besides financial benefits, using renewable systems decreases the emission of carbon dioxide into the environment. Here the annual emissions of CO<sub>2</sub> is 7.369,84 kg in building type 1 where as for the building type 2 this amount is 985,35 kg. This analysis shows that by applying low energy building principles on this building, the emission would be reduced by 6.384,49 kg per year.

### 3. Economic and Financial Analysis

The aim of economic-financial analysis is to assess the financial capabilities of the investor and the financial requirements of the investment project. The profitability projection is carried

out through the estimation of total income and expenses, investments in working capital, sources of financing and financial liabilities, and profit and loss account, economic and financial flow. For the purpose of this project, one year is considered. According to the current situation in the property market, the assumption is that both residential properties will be sold in one year. The investment will be financed using project financing, which is often used in the construction sector. Project financing is a specific form of project development financing in which lenders expect the loan to be repaid from the revenue which the project will generate (Aralica et al., 2007). Investor predict that the bank will approve a short-term loan with an annual interest rate of 4.00% with quarterly interest repayments.

### 3.1 *Projection of the total revenue*

Total revenues are monitored over a period of one year that is estimated to be sufficient to complete construction and sale. Based on the sales prices defined by the market analysis, the expected total income from the sale of both apartments in variant 1 would be 2,987,054.40 kn (12,210.00 kn / m<sup>2</sup>), and in variant 2 would be 3,525,262.40 kn (14,410.00 kn / m<sup>2</sup>).

Table 7. Projection of the total revenue

<i>Building type 1.</i>	
Total revenue	2,987,054.40 kn
<i>Building type 2.</i>	
Total revenue	3,525,262.40 kn

- Economic life of the project – 1 year

### 3.2 *Projection of Profit and Loss Statement*

For the purposes of the investment project, a budget (planned) financial report has been prepared, which aims to determine the performance during the investment period serves as a basis for performance evaluation. Profit and Loss Statement shows a company's ability to generate sales, manage expenses, and create profits (Corporate Finance Institute, 2019). Operating income consists of income from the sale of apartments, and operating expenses are all investment costs. Operating profit (EBIT - Earns before Interests and Taxes) is shown in Table 8. In both variants, the project ultimately generates positive net receipts. In variant 1, the net profit at the end of the project was 962,558.00 kn, while in the second one is 1,166,421.00 kn.



Table 8. Profit and Loss Statement

<i>Building type 1</i>		1 <sup>st</sup> month	2 <sup>nd</sup> month	3 <sup>rd</sup> month	...	9 <sup>th</sup> month	10 <sup>th</sup> month	11 <sup>th</sup> month	12 <sup>th</sup> month
I	Total Revenue	0	0	0		0	1,712,086	0	1,274,968
I	Operating costs	95,760	139,990	126,777		126,777	23,553	7,300	7,300
	EBIT	-95,760	-139,990	-126,777		-126,777	1,688,533	-7,300	1,267,668
I	Financial costs	0	0	0		0	10,322	0	0
I	Gross profit	-95,760	-139,990	-126,777		-126,777	1,678,211	-7,300	1,267,668
V	Profit tax	0	0	0		0	302,078	0	228,180
	Net profit	-95,760	-139,990	-126,777		-126,777	1,376,133	-7,300	1,039,488
	Cumulate	-95,760	-235,750	-362,527		-1,445,763	-69,630	-76,930	962,558
<i>Building type 2</i>		1 <sup>st</sup> month	2 <sup>nd</sup> month	3 <sup>rd</sup> month	...	9 <sup>th</sup> month	10 <sup>th</sup> month	11 <sup>th</sup> month	12 <sup>th</sup> month
I	Total Revenue	0	0	0		0	2,020,570	0	1,504,692
I	Operating costs	95,760	139,990	150,042		150,042	23,553	7,300	7,300
	EBIT	-95,760	-139,990	-150,042		-150,042	1,997,017	-7,300	1,497,392
I	Financial costs	0	0	0		0	12,649	0	0
	Gross profit	-95,760	-139,990	-150,042		-150,042	1,984,368	-7,300	1,497,392
V	Profit tax	0	0	0		0	357,186	0	269,531
	Net profit	-95,760	-139,990	-150,042		-150,042	1,627,182	-7,300	1,227,862
	Cumulate	-95,760	-235,750	-385,792		-1,681,323	-54,141	-61,441	1.166,421

### 3.3 Financial flow

The financial flow shows the inflow and outflow of cash and cash equivalents over a specified period. Financial potential, made up of available means of payment for the duration of the project, is a prerequisite for investment. The financial flow assesses the liquidity of the project and is the basis for calculating the cash flow for the balance sheet. Table 9 shows the cash flows for the investment, which show that the company will be able to pay all the liabilities. On the other hand, total expenditures consist of material costs, labor costs, other material costs and liabilities to creditors.

Table 9. Financial flow

<i>Building type 1</i>		1 <sup>st</sup> month	2 <sup>nd</sup> month	3 <sup>rd</sup> month	...	9 <sup>th</sup> month	10 <sup>th</sup> month	11 <sup>th</sup> month	12 <sup>th</sup> month
	INFLOWS	343,012	210,322	289,994		148,677	1,733,986	14,600	1,282,268
I	Total Revenue	0	0	0		0	1,712,086	0	1,274,968
I	Sources of financing	343,012	210,322	289,994		148,677	21,900	14,600	7,300
	OUTFLOWS	95,760	139,990	126,777		126,777	1,066,115	7,300	7,300
	Net cash flow	247,252	70,332	163,217		21,900	667,871	7,300	1,274,968
	Cumulated cash flow	247,252	317,585	480,801		952,590	1,620,461	1,627,761	2,902,729
<i>Building type 2</i>		1 <sup>st</sup> month	2 <sup>nd</sup> month	3 <sup>rd</sup> month	...	9 <sup>th</sup> month	10 <sup>th</sup> month	11 <sup>th</sup> month	12 <sup>th</sup> month
	INFLOWS	343,012	210,322	313,259		171,942	2,042,470	14,600	1,511,992

I	Total Revenue	0	0	0	0	2,020,570	0	1,504,692
I	Sources of financing	343,012	210,322	313,259	171,942	21,900	14,600	7,300
OUTFLOWS		95,760	139,990	150,042	150,042	1,301,094	7,300	7,300
I	Net cash flow	247,252	70,332	163,217	21,900	741,376	7,300	1,504,692
	Cumulated cash flow	247,252	317,585	480,801	949,682	1,691,059	1,698,359	3,203,051

### 3.4 Balance sheet projection

The balance sheet is one of the three fundamental financial statements and is key to both financial modeling and accounting (Corporate Finance Institute, 2019). The balance sheet is divided into two sides (or sections). The left side of the balance sheet outlines all a company's assets. On the right side, the balance sheet outlines the companies liabilities and shareholders' equity. Since the entire project is completed within one year, the balance sheet shows current assets, equity and current liabilities. Table 10. shows investors balance sheet in both variant of building.

Table 10. Balance sheet

	<i>Building type 1.</i>	<i>Building type 2.</i>
ASSETS		
Current assets	4,458,067.00	5,228,927.00
TOTAL ASSETS	4,458,067.00	5,228,927.00
LIABILITIES AND EQUITY		
Capital	1,931,589.00	2,231,910.00
Current liabilities	2,526,478.00	2,997,017.00
TOTAL LIABILITIES AND EQUITY	4,458,067.00	5,228,927.00

#### 1. Evaluation of investment project

Evaluation of an investment project is a key element in the decision of project realization. It shows the degree of justification for investing in a project. Below, a dynamic project assessment, i.e. an economic market assessment for both variants of the planned investment, will be shown. The dynamic estimation is based on data from the economic flow of the project, which is shown in Table 11.

Table 11. Economic flow

<i>Building type 1</i>		1 <sup>st</sup> month	2 <sup>nd</sup> month	3 <sup>rd</sup> month	...	9 <sup>th</sup> month	10 <sup>th</sup> month	11 <sup>th</sup> month	12 <sup>th</sup> month
	INFLOWS	0	0	0		0	1,712,086	0	1,274,968
I	Total Revenue	0	0	0		0	1,712,086	0	1,274,968
	OUTFLOWS	95,760	139,990	126,777		126,777	23,553	7,300	7,300
	Net cash flow	-95,760	-139,990	-126,777		-126,777	1,688,533	-7,300	1,267,668
	Cumulated cash flow	-95,760	-235,750	-362,527		-1,432,860	255,674	248,374	1,516,042
<i>Building type 2</i>									

		1 <sup>st</sup> month	2 <sup>nd</sup> month	3 <sup>rd</sup> month	...	9 <sup>th</sup> month	10 <sup>th</sup> month	11 <sup>th</sup> month	12 <sup>th</sup> month
	INFLOWS	0	0	0		0	2,020,570	0	1,504,692
I	Total Revenue	0	0	0		0	2,020,570	0	1,504,692
	OUTFLOWS	95,760	139,990	150,042		150,042	23,553	7,300	7,300
I	Net cash flow	-95,760	-139,990	-150,042		-150,042	1,997,017	-7,300	1,497,392
	Cumulated cash flow	-95,760	-235,750	-385,792		-1,665,512	331,506	324,206	1,821,598

The evaluation of investment project is calculated using the net present value (NPV) and internal rate of return (IRR).

#### 4.1 Net Present Value – NPV

Net Present Value (NPV) is the value of all future cash flows (positive and negative) over the entire life of an investment discounted to the present (Corporate Finance Institute, 2019). If the net present value is positive, the investment project is acceptable for financing. If the net present value equals zero, then the project is marginally acceptable. For the purpose of calculating the dynamic assessment of an investment project in both variants, the discount rate of 4% is used (it is equal to the interest rate of the loan).

In case of *Building type 1*, NPV is 764.609,94 kn. In case of *Building type 2*, NPV is 934.992,16 kn. It can be concluded that in both cases, project is acceptable for financing.

#### 4.2 Internal return rate – IRR

The Internal Rate of Return (IRR) is the discount rate that makes the net present value (NPV) of a project zero. In other words, it is the expected compound annual rate of return that will be earned on a project or investment (Corporate Finance Institute, 2019). If the IRR is greater than or equal to the cost of capital or interest rate of the loan, the company would accept the project as a good investment.

In case of *Building type 1*, the IRR is 13.46 % and in case of *Building type 2*, the IRR is 14.10 %. According to the IRRs, it can also be concluded that in both cases, project is acceptable for financing.

## 5. Conclusion

The aim of this publication was to analyze the feasibility of the construction of a residential building in two types: type 1 – conventional construction techniques with minimal necessary energy efficiency; type 2 – low-energy building. According to the initial investment analysis the building type 2 was about 19% more expensive than the type 2 building (low-energy building).

To analyze the feasibility of low-energy buildings in comparison to conventional building types technical and technological analysis was made resulting with a definition of bill of quantities for both building types and the energy consumption budget was assessed. Based on the obtained data, an economic and financial analysis was made for both building types with

different initial costs and expected revenues, and finally an estimate was obtained based on two dynamic methods – NPV and IRR.

The results of the feasibility analysis has shown that both investment options enable return of the investment. In both cases NPV including the discount rate is positive. For the building type 1 IRR is 13,46%, whereas for the building type 2 IRR equals 14,10%, both of which is greater than 0 and the financing cost.

Two critical variables, sales price and operating costs, were observed to analyze the sensitivity of the project to changes in input variables. It was concluded that project revenues must be reduced by 40% to make the project unprofitable. Increasing operating costs reduces net present value and internal rate of return, but not to the extent that it would affect cost effectiveness.

It can be concluded that investment in low-energy buildings is the future of the construction sector putting the accent on environment protection and job creating besides only the revenue. Prices for systems using renewable energy sources are becoming more acceptable. In addition, in recent years, incentives for low-energy building construction, as well as changes to legal frameworks, have been increasing. However, society has not yet developed sufficient awareness of climate change and the need for more efficient use of energy. Croatia's biodiversity is extremely large, which is why it is necessary to act to promote sustainability by educating the population and stimulating social and economic development in this direction.

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# Environmental Management Systems as a Driver for Sustainability in Construction Companies

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## Abstract:

The construction industry relies on nature for its raw material; hence the consumption of this material affects the environment and it also emits large volume of greenhouse gases. Hence the implementation of environmental management systems will contribute greatly in the reduction of the depletion of the environment by the construction industry. The study is conducted to investigate the drivers of implementing environmental management systems in South African construction companies. A quantitative research methodology was adopted, strategically structured questionnaires were designed 85 were sent and 65 returned, the data obtained from the survey were gathered and analyzed using Ms Excel and SPSS software. The findings of the study revealed that top leaders and middle management should commit to improve or protect the environment; reduce cost of implementing EMS, use of equipment that are environmentally friendly, tax exemption, EMS training and enforcement of EMS by government. The government should enforce companies to comply with EMS or make it mandatory before execution of a project. Moreover, the accreditation body should reduce the price of external audit and certification in order to give access to most companies.

*Keywords: construction companies; environmental management system; sustainability.*

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## 1. Introduction

The construction industry is an engine for economic growth of any country (Mashwama et al., 2016). Furthermore, according to the CIDB (2015), between 2008 and 2016 the construction industry accounted for about 9.6% of the average gross domestic product. In addition, it provides employment to 8% of the total work force of South Africa (Enshassi *et al.*, 2006). However, the activities within the construction industry has a significant impact on the environment (Selhi, 2006). The construction industry emits large volume of greenhouse gases. It has been reported by Acquaye and Duffy, (2010), that the construction sector produced 17% of the total greenhouse gas emissions in Ireland. Selhi, (2006) asserts that the activities of the construction industry are responsible for between 25% and 30% towards the depletion of the Ozone layer and non-renewable resources. In addition, despite all the researches done, conference conducted, policies and regulations established, the contribution of the construction industry to the environmental pollution still high, hence the research.

## *1.1 Impact of construction activities on the environment*

### *1.1.1 Consumption of renewable and non-renewable materials*

The construction industry is a primary source of environment degradation due to the use of non-renewable resources and it relies on the nature for raw materials (Sterner, 2002). The construction process involves different materials from the nature such as aggregate, wood, sand etc (Ametepey & Aigbavboa, 2014). According to Dixon (2010), 40% of environmental raw materials is consumed by the construction industry and the consumption of this materials affect the environment from their extraction up to their use.

### *1.2 Adverse effect.*

The adverse effect refers to the negative consequences that follow a good intention. The construction industry causes an irreversible loss of land through the construction of roads, rails, building and dams (Chanda & Aigbavboa, 2017). Therefore, the construction of a building structure on a land, is the loss of forest, farm and for trees produces oxygen and consume Carbone dioxide which contribute to the ecological balance (Kibert 2013).

### *1.3 Energy consumption*

The construction industry is the biggest source of energy consumption. Selhi, (2016), states that 40 to 50 percent of the renewable and non-renewable energy is consumed by the construction industry all over the world. Sterner (2002) study assert that the construction industry consume 40% of energy that is from non renewable resources such as coal and oil, which produces carbon dioxide that has negative impact to the environment. This evidence shows that the construction industry pollutes the environment by consuming a significant quantity of energy.

### *1.4 Water consumption*

Fresh water is one of the scarce resource and yet the construction industry uses fresh water for building. Dixon (2010) in his study found that the construction industry uses 50% of the total amount of fresh water produced. For example, according to the construction practice, the water used for concrete fabrication, mortar mix has to be a pure drinkable water. Water finds it further use in construction for dust elimination, cleaning, etc. Furthermore, impact of construction activities on the environment also include Air pollution and water pollution.

## **2. Environmental regulation**

In 1969, after the United State has rewritten the Environmental Policy into its constitution, developed countries started implementing the environmental assessment policy to check the impact of human activities on the environment (Sakr, 2010). South Africa and other developing countries have taken longer time in adopting and implementing the environmental policies (du Plessis, 2002). In 1974 the Environmental Impact Assessment was discussed among the South African academics to increase awareness. In 1982 the environmental conservation act (Act. 100) was included in the constitution. The act 100 was revised and policies were made in 1989

to achieve a proper Environmental management but the policies where not mandatory (SEFLII, 2009).

### **3. Element of environmental management system**

The main purpose of the Environmental Management system is to help company control, moderate or to eliminate the environmental impact at the company level (Da Fonseca, 2015). The ISO is one of the International Environmental Management System Standard accepted all over the world and implemented on the voluntary basis (Edwards, 2003:8). The Environmental Management System standards ISO14001: 2004, revised in 2010, is based on six pillars which are the six elements of the EMS namely: Understand the contest of the company (ISO 14001:2004 clause 4.1); Environmental policy company (ISO14001:2004 clause 4); Planning (ISO14001:2004, clause 4.3); Implementation (14001:2004 Clause 4.4); Checking and making corrective actions (ISO 14001:2004 Clause 4.5); Management review (ISO14001:2004 Clause 4.6).

### **4. Drivers of environmental management**

The drivers of the environmental management system are those factors or situation that ensures or motivate the implementation of the environmental management system or the adoption of the standards (Abidin, 2010). Following is a brief overview of EMS drivers:

#### *4.1 Government intervention*

Government has to monitor the EMS, by legally enforcing the implementation of the EMS. It has to be mandatory before the execution of a project and monitored throughout the life cycle of the project (Selih, 2007). Furthermore, subsidizing the cost incurred of compliance can be a big external driver for the companies to comply (Vilchez, 2016).

#### *4.2 Involvement of Top Management*

The management of a firms play a big role in driving the implementation of the EMS, by providing training and awareness to the staff; establishing a reward system; have access to the environmental management records (Chan & Wong, 2006).

#### *4.3 Environmental friendly material and technology.*

Lack of awareness or knowledge of user friendly material to the environment contribute to the poor implementation of EMS (Selih (2007:222).

#### *4.4 Availability of resources*

According to Abramyan (2016), the implementation of EMS increases the construction budget. The availability of addition fund and resources in a project would assist the implementation of EMS without affecting the marginal interest for the contractor (Chanda & Aigbavboa, 2017).



#### *4.5 The corporate policies*

The corporate policy play a big role in the implementation of the EMS within the company. Since, it contains the mission and objectives of the company. Company corporate policies act is a huge motivator for employees to implement EMS (Selih, 2007).

#### *4.6 The local regulation*

The expectation of the local environmental regulation can be a good motivation for a company to establish the environmental management system. Furthermore, fines should be in place for non-compliance, fines are not beneficial for the firm so it will push the contractor to comply (Selih, 2007).

#### *4.7 Company image*

The improvement of the image of the company is an external driver that can motivate the companies to comply (Boiral, 2007).

#### *4.8 The advantages of EMS to an organization*

It should be noted that companies can adopt or implement the EMS if tax discount, improvement of operation processes within the company, and reduction of waste can be witnessed (Tse, 2001).

### **5. Mpumalanga Province**

Mpumalanga means the place of the rising sun and people are drawn to the province by its magnificent scenery, fauna and flora. The province is the second smallest province in South Africa yet it has fourth –largest economy. It's situated mainly on the high plateau grasslands of the middleveld. Mpumalanga has network of excellent roads and railway connections thus making it highly accessible (Mpumalanga, 2018). The province is a tourism destination and it's a home, of over 4 million people, the principal languages are siSwati and isiZulu. The province is a summer-rainfall area divided by the escarpment into the Highveld region with cold frosty winter and lowveld region with mild winters and subtropical climate. Mpumalanga is the second largest citrus producing area in South Africa and is responsible for one third of the country's export in oranges. Mpumalanga is very rich in coal reserves. The province house the country three major power stations, of which are the largest in the southern hemisphere (Mpumalanga, 2018).

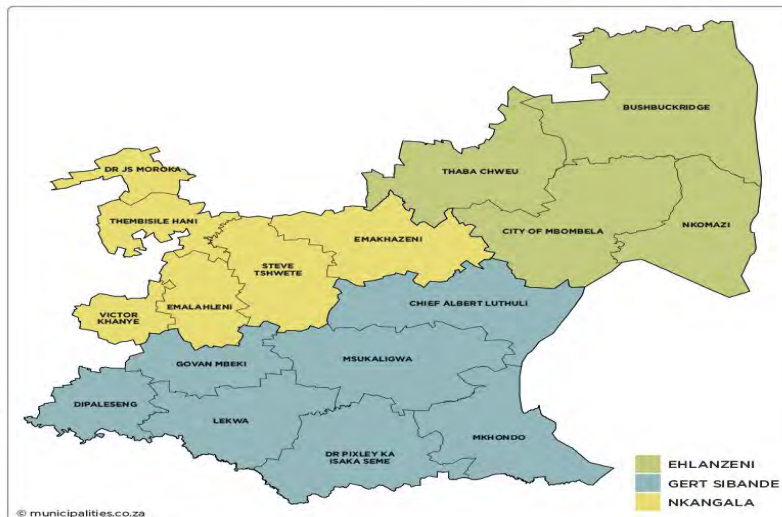


Figure 1: Mpumalanga map

## 6. Research Methodology

### 6.1 Research approach and design

Quantitative approach method was adopted to investigate the drivers of environmental management systems for sustainability in construction companies. The study was carried out in Mpumalanga Province of the Republic of South Africa. 80 Questionnaires were distributed and 65 were brought back which were all valid and usable. A well-structured questionnaire was distributed to different construction companies in Mpumalanga Province, registered with CIDB. The questionnaires were sent via e-mails, some were delivered to the known construction firms by the researcher. The study was conducted from reliable scholarly sources such as articles, journals, books, publications, websites and site experience on the field.

### 6.2 Statistical package for the social science (SPSS)

The quantitative data collected was analysed with Statistical Package for the Social Science (SPSS) a computer programme which is used for analysing data concerned with social phenomena. The software was used to generate various statistical, including descriptive statistic, which provides a basic summary of all variables in the data (SPSS, 2004). The benefits of using SPSS is that it allows for scoring and analysing quantitative data at speed and it can also be used to perform multivariate analysis. SPSS also helps to present the data in a logical format (SPSS, 2004) thereby reducing time spent on calculating scores. However, accuracy in results is highly dependent on inputs, hence the need to accurately capture data from the questionnaire.

### 6.3 Point likert scale

5- point likert scale was adopted for the study which gave a wider range of possible scores and increase statistical analyses that are available to the researcher. The first likert scale read is on agreement form as follows:

- 1- Strongly Disagree (SD)
- 2- Disagree (D)
- 3- Neutral (N)
- 4- Agree (A)
- 5- Strongly Agree (SA)

The second likert scale read is on likelihood as follows:

- 1- Extremely Unlikely (EU)
- 2- Unlikely (U)
- 3- Neutral (N)
- 4- Likely (L)
- 5- Extremely Likely (EL)

The 5 point scales were transformed to mean item score abbreviated as (MIS).

#### 6.4 Computation of the mean item score (MIS)

The computation of the mean item score (MIS) was calculated from the total of all weighted responses and then relating it to the total responses on a particular aspect. The mean item score was adopted to rank the factors from highest to lowest. The Mean Item Score (MIS) is expressed and calculated for each item as follows:

$$\text{MIS} = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{\sum N} \quad (1)$$

Where;

$n_1$  = number of respondents for strongly disagree

$n_2$  = number of respondents for disagree

$n_3$  = number of respondents for neutral

$n_4$  = number of respondents for agree

$n_5$  = number of respondents for strongly agree

$N$  = Total number of respondents

## 7. Findings

### 7.1 Level of awareness of EMS

Figure 2, below demonstrate the level of awareness of EMS of respondent in their companies out of 65 respondent 58% of the respondents are well aware of EMS, 42% of the respondents were currently not aware of EMS.

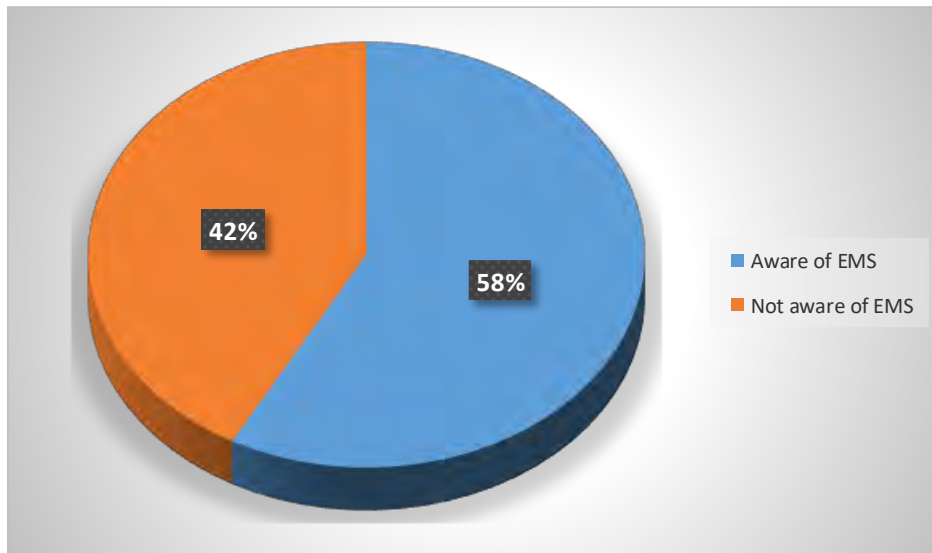


Figure 2: Level of awareness of EMS

### 7.2 Level of implementation of EMS

The respondents were asked based on their experience on the level of implementation of EMS in their companies. Generally 21% of the respondent acknowledged that the implementation of accredited EMS is implemented in their companies; 15% of the respondent believed informal EMS was implemented in their organization and 64% of the respondent believed its not implemented in their organization's.

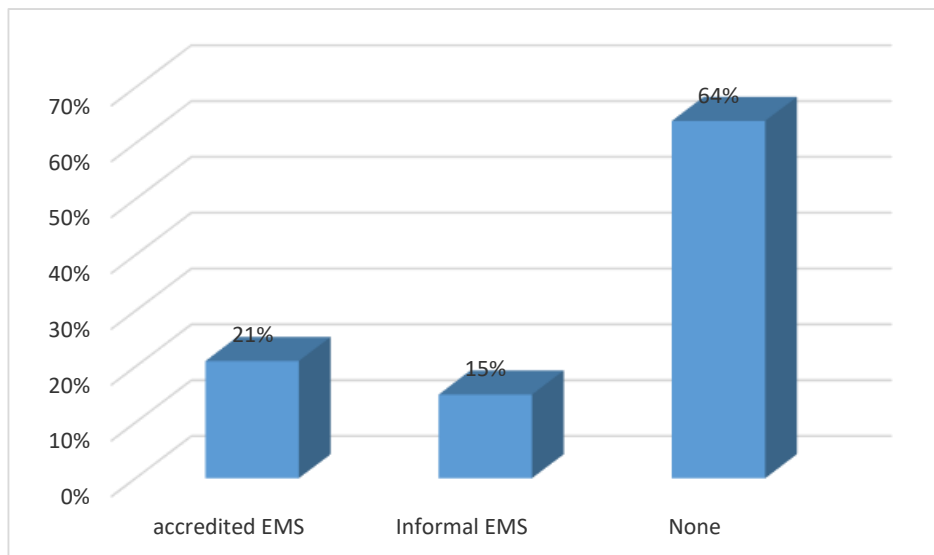


Figure 3: Level of implementation of EMS

### 7.3 Environmental management systems drivers

The respondents were asked based on their experience as to which EMS drivers could lead to proper implementation. Generally the driver that was ranked first was the Involvement of top leader and Middle Management in improving EMS with (MIS=3,98 & STD=0,985); followed

by Reduced cost of implementing EMS (audit) which was ranked second with (MIS=3,92 &STD=1,165); Use of equipment that are environmental friendly and Tax reduction by the government were ranked third with (MIS=3,87; STD=1.12 &1,156 respectively); EMS training was ranked fourth with (MIS=3,78 & STD=1,056); Enforcement of EMS by government was ranked fifth with (MIS=3,69 & STD=0,897); Inspection of equipment for Environmental Management and well defined responsibility on the EMS were ranked sixth with (MIS=3,61& STD=0.797& 0,995 respectively); Presence of experienced professionals regarding EMS was ranked seventh with (MIS=3,58 & STD=0,789); Easy access to Environmental Management's records was ranked eighth with (MIS=3,56 & STD=0,978); Establishment of measures of protection of environment per production and Provide, maintain or increase client satisfaction was ranked ninth with (MIS=3,48 & STD=0.987 &1,142 respectively); re-utilization of resources and availability of resources input to improve the environment were ranked tenth with (MIS=3,39& STD=1.089 &1,142 respectively); Maintain company's image was ranked eleventh with (MIS=3,33 & STD=1,24); Effective implementation of relevant EMS Regulation was ranked twelfth with (MIS=3,21& STD=1,156); Part of the requirement during tendering for construction companies was ranked thirteenth with (MIS=3,2 & STD=0,928); Protection measure in material handling and Easy access to mechanism that reduce waste were ranked fourteen with (MIS=3,19& STD=0.819 &1,178 respectively ) and lastly ranked was Innovation in technology with (MIS=3,08 & STD=1,248)

Table: 1 Drivers of Environmental Management

Drivers of Environmental Management	M	STD	R
Involvement of top leader and Middle Management in improvement of EMS	3,98	0,985	1
Reduced cost of implementing EMS (audit)	3,92	1,165	2
Use of equipment that are environmental friendly	3,87	1,12	3
Tax reduction by the government	3,87	1,156	3
EMS training	3,78	1,056	4
Enforcement of EMS by government	3,69	0,897	5
Inspection of equipment for Environmental Management	3,61	0,7968	6
well defined responsibility on the EMS	3,61	0,995	6
Presence of experienced professionals regarding EMS	3,58	0,789	7
Easy access to Environmental Management's records	3,56	0,978	8
Establishment of measures of protection of environment per production	3,48	0,987	9
Provide, maintain or increase client satisfaction	3,48	1,142	9
re-utilization of resources	3,39	1,089	10
availability of resources input to improve the environment	3,39	1,142	10
Maintain company's image	3,33	1,24	11
Effective implementation of relevant EMS Regulation	3,21	1,156	12
Part of the requirement during tendering for construction companies	3,2	0,928	13
Protection measure in material handling	3,19	0,819	14
Easy access to mechanism that reduce waste	3,19	1,178	14
Innovation in technology	3,08	1,248	15

## 8. Conclusion

Implementation or adoption of environmental management systems by South African companies is very poor. The few companies that are implementing EMS are complaining that it is an expensive exercise to do, while others prefer to have it in their company profile and don't they don't implement it. Furthermore, the top five drivers of EMS were identified as involvement of top leader and Middle Management in improving EMS; reduced cost of implementing EMS (audit); Use of equipment that are environmental friendly and Tax reduction by the government; EMS training; Enforcement of EMS by government. From the findings it can be deduced that if EMS can be forced by government and provide training to companies, companies would comply and also the exemption of tax on the user friendly material would contribute greatly to the implementation of EMS by companies in the Mpumalanga Province of South Africa. Therefore, the cost of audit of EMS must be lowered to encourage companies to implement and save the environment from depletion.

## 9. Recommendation

It is recommended that government should exempt tax on materials that are user friendly and companies should be forced in implementing EMS or fines should be levied to the company that ignores. The accreditation body should also reduce the price of external audit and certification in order to give access to the service to all type of project.

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# **Research and Education in Construction**



# The Learning Competencies of Project Managers through the Use of BIM – Comparison Study

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## **Abstract:**

Project manager's duties include a range of activities from administrator of the project to team leader. Therefore, to successfully execute project its manager needs a unique set of capabilities and competencies. PMI standard defines knowledge competencies, performance competencies and personal competencies like the main competence areas. These competencies are often achieving by information and communication technology. BIM technology is one of the most important tool for decision-making of project managers. The research discusses the issue of learning project manager's competencies by BIM technology. The main aim of the paper is to compare level of project manager competences learning and achieving by BIM technology. Main objective of research was set to analyze the learning competencies of project managers through the use of BIM and prepare model of these competencies. That means set which competencies and what intent impact on learning competencies by BIM using. Data collection is providing by questionnaire and data analyses are provide by standard statistical methods.

**Keywords:** *learning competencies; project managers; BIM*

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## **1. Introduction**

Construction projects are strictly defined by result requirements, the cost and time constraints, and are bounded by the environment in which are implemented (Mandičák and Mesároš, 2017). As a result, a set of project manager's activities typically include motivation, time, cost, scope, quality management and various administrative duties (Gaddis, 1959). Construction project management refer to project management tasks and managers based on their past experience. It's more useful than following a theoretical approach in new case (Maqsood *et al.*, 2006). On-time knowledge and information in construction field can involve project managers and engineers' moderate problems on a construction worksite and reduce the time and cost of construction project (Shu-Hui, 2012). Knowledge of project management theory is important to participate on a project (Peterson, 2011). Despite of this fact, the development and achieving of digital competences for managers is usually only answer to the current problem (Kolarić, 2018). Learning process is a first step and presumption for better results of every construction manager. The achievement of higher level of competencies increases the precondition for its successful results in the management of construction projects (Mesároš *et al.*, 2017). Increasing of information and communication technology impact on productivity levels and developing of managerial competencies of managers (Bolek *et al.*, 2016). Knowledge achieved by education process are very beneficial, however practice and experiences are another a necessary component for proper decision-making and management

(Mesárošová and Mesároš, 2012). According to next research, university with train sheep program have better results between their alumni manager's results. The study shown increasing trend in use of training a work experience at universities with aspects on positive results in this issue (Cowling, 2009). Another case study highlighted on relationship between education and employability (Lemus, 2013).

El-Baz and El-Sayegh described four groups managerial competencies for construction industry. There are technical competencies, management competencies, leadership management and financial competencies (El-Baz and El-Sayegh, 2007). Technical competencies include statistical analysis, decision analysis, resource optimization, information technology control, SCM and so on. Management competencies include typical planning and managerial competencies as strategic and operation planning, human resource planning, change management and so on. Leadership competencies are ability of managers have to effective communication, vision, responsibility and motivation. Last one group represents financial competencies. It includes cost management ability, financial analysis, accounting and so on. Other researcher described project manager competencies as ability to have different approach towards classic management functions, ability to finish tasks within the time with no specific information at the early stages of the project and that is related to the ability of taking risks, shall have power in the organization to delegate responsibility to subordinates and so on (Gaddis, 1959). Kerzner in his study mentioned leadership abilities, creativity, ability to make decisions, ability to identify problems, ability to organize work to subordinates, effectiveness, ability to persuade and having ambition, vision and leadership abilities (Kerzner, 2005). Duties of project manager include a range of activities from administrator of the project to team leader. Therefore, to successfully execute project its manager needs a unique set of capabilities and competencies (Huemann, 2007). Project Manager Competency Development (PMCD) by Project Management Institute (PMI) standard defines three project managers' competence areas. There are knowledge competencies, performance competencies and personal competencies (PMI, 2007). International Project Management Association defined twenty technical competency elements and fifteen behavioural competency elements. It includes eleven contextual competency elements too (Caupin, 2009). Dziekoński defined management skills in construction industry. There are ability to make decisions, ability to assess the impact of actions taken Ability to formulate goals, ability to organize work to subordinates Ability to communicate, ability to motivate team members, ability to resolve conflicts and ability to negotiate. Next skills or competencies help in solving problems, focusing on the objectives (Dziekoński, 2017).

BIM is an intelligent 3D model-based process that gives architecture, engineering, and construction professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure (Tkáč and Mesároš, 2015). In the minding of construction industry, it using well-structured digital information (Kreider and Messner, 2009). Application of BIM is steadily gaining popularity in construction industry and as such BIM knowledge represents important learning outcome in higher students' education. The issue of problem in this field, it is connected with BIM education within Construction Management field is to define learning outcomes, curriculum of courses and specific knowledge which is necessary for future construction and project managers (Kolarić *et al.*, 2018). Requirement of BIM education

process increasing highlights Uhm's eight BIM job types, which starting and included construction project manager. Even though BIM shows promising results and is the current trend in the construction industry, and many countries are obliged to use it, education of construction engineers (Kolarić, 2018). On the second hand, BIM technology can be a learning tool in practice. And that's main objective of this study. Building information modelling (BIM) may currently be considered the fastest developing concept in construction management (Galić *et al.*, 2017). Building Information Modeling content has become the most advanced approach to integrating information in construction projects from very earliest project phases onto the projected (Kolarić *et al.*, 2016).

In the context of BIM and learning competencies of projects was set the most used and mentioned project competencies and their main groups. There were set on literature review and mentioned sources. All of the above studies were largely theoretically processed. In this case, the experts themselves are also important. This means the view of managers who are in the real world and perceive these competences from experience. Selected managers, considered experts in the subject, have collaborated in the selection of the competencies examined. That was reason the final table was modified. Some of the above-mentioned competences were not important, according to several experts. These were left out of research. On the contrary, the view of experts is important. These experienced managers have added some other important competencies that need to be explored in detail.

Table 1. Groups of competencies and competencies of project managers (source: own processing based on literature review and experts view)

Technical competencies	Behavioural and personal competencies	Financial and economic competencies
<ul style="list-style-type: none"> <li>• Ability to organize work to subordinates</li> <li>• Ability to make decisions</li> <li>• Ability to formulate goals</li> <li>• Ability to use project management software</li> <li>• Ability to design project</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to communicate</li> <li>• Ability to motivate team members</li> <li>• Help in solving problems</li> <li>• Ability to resolve conflicts</li> <li>• Ability to humans resource planning</li> <li>• Ability to motivate</li> <li>• Ability to take a responsibility</li> </ul>	<ul style="list-style-type: none"> <li>• Ability to manage the scope, time and cost of the project</li> <li>• Ability to cost management</li> <li>• Budgeting and accounting</li> </ul>

## 2. Methodology

### 2.1 Research problem and objectives

BIM technology represents important tool in construction project management. On the other hand based on literature review, it's tool for learning and development of the project managers competencies too. Main objective of research was set to analyze the learning competencies of project managers through the use of BIM and prepare model of these competencies. That means set which competencies and what intent impact on learning

competencies by BIM using. Based on theoretical analyses of researches and experts were set main competencies of project managers.

## 2.2 Data collection and research sample

The data collection was done by questionnaire survey form. The questionnaire is one of the most common methods of research use. It is used for mass and faster detection of facts, attitudes, values, opinions, etc. The questionnaire contained simple and comprehensible questions about the learning competencies of project managers development by use of BIM technology. The structure of the questionnaire was basic information about the project managers and construction projects. Another part of the questionnaire had direct questions about the research problem. Project managers used the Likert Scale for the quantification of impact in the main research questions (1 – low impact on the learning competencies, 5 – high impact on the learning competencies).

The research sample consisted of project managers participated in construction projects in Slovakia. Project managers and construction projects were selected by random selection. Return rate was 4.89%, it means 147 project managers. Research sample so includes 2% project managers of large companies, 19% project managers worked in medium sized companies and 79% of project managers works in small and microenterprises.

## 2.3 Data processing

The AHP method was used to determine the weights and the resulting model. The Analytic Hierarchy Process (AHP) method is a comprehensive methodology developed for decision-making in multiple choice. The basis for decision making is empirical decision-making criteria (Saaty, 2008). The basis for using the AHP method is to outline the whole decision problem as a hierarchical structure. It is a classic tree representation and branching of the main problem to sub-areas that affect the main objective. The basis of the AHP method is the comparison of the pairs of options where the pairs are compared with each other (Saaty and Rozann, 2009). The intensity or weight of each criterion, whether in our case the selected information and communication technologies, is determined by a recognized team of experts (Ramík, 1999). In our case, they were project managers on behalf of individual construction projects, which were further specified in the "research sample" section. These experts were to determine the impact of the use of BIM technology on their learning competencies. This method is based on the value of the information obtained. The main purpose of this modification of the AHP method is to exclude subjective assessment and to ensure independence in assessing individual criteria based on the amount of data (Ching-Lai and Kwangsum, 1981). Entropy measures the information content of a set of data (Mesároš *et al*, 2006). It is a criterion for the amount of uncertainty represented by a discrete probability distribution. The chosen method works by determining the weight based on the "amount" of the data it contains. Main model is results analysis and represents the intensity of each competency acquired through the use of BIM technology.

## 3. Results and discussion

Entropy measures the information content of a particular data set. It is a criterion for the amount of uncertainty represented by a discrete probability distribution. The chosen method

works by determining the weight based on the "amount" of the data it contains. In other words, the more information the selected set of values contains, the more important the selected criterion will be. The intensity of interaction of selected elements must be clearly quantified, which is the basis for the whole process to be mathematically processed and evaluated. The main level or main problem is defined at the top of the hierarchy. This main element has a weight value of one. This is then divided into elements at level 2. The formulation of the main objective emerged from the research questions determined on the basis of the theoretical analysis of the issue and the following basic research questions for the area.

1<sup>st</sup> level: Main objective of the AHP model – Analyses the learning competences process through use of the BIM technology

2<sup>nd</sup> level: Partial Objectives of the AHP Model - Quantify the impact of the use of BIM technology on selected groups of project managers' competencies.

3<sup>rd</sup> level: Quantify the impact of the use of BIM technology on project managers' competencies.

To quantify the impact of the use of specific ICTs on the overall cost of construction projects, the following were taken into account:

- Technical competencies - ability to organize work to subordinates, ability to make decisions, ability to formulate objectives, ability to use project management software, ability to design project,
- Behavioral and personal competencies - ability to communicate, ability to motivate team members, help in solving problems, ability to resolve conflicts, ability to manage human resource planning, ability to take responsibility,
- Financial and economic competencies - ability to manage the scope and time of the project, ability to cost management, ability to give a budgeting and accounting

These results are shown in Figure 1. For more details, BIM technology impact especially on technical competencies. This group of managers' competencies achieved a value of 0.54, which represents the highest value on the learning competencies of project managers. Next group was set as financial and economic competencies. Last one, it was so-called group of behavioral and personal competencies with a value of 0.17.

Separately, BIM is the most positive in development of ability to design project. It achieved a value of 0.19 and it's the highest value. It's interesting that this answer was chosen by more than 50% of respondents as more important. Ability to manage the scope and time of the project is second in this case. Project managers achieved these competencies when using BIM technology. Ability to use project management software was set as third important and most positive learning competency by BIM technology. Other competencies achieved the highest value as ability to make decisions, ability to formulate objectives (technical competencies), and ability to cost management, ability to give a budgeting and accounting (financial and economic competencies). What is a very important and interesting result, generally behavioral and personal competencies achieved a low value. BIM technology has a positive and significant impact on learning

and development of technical competencies, but not more significant on generally behavioral and personal competencies. For more details about quantified results see fig. 1.

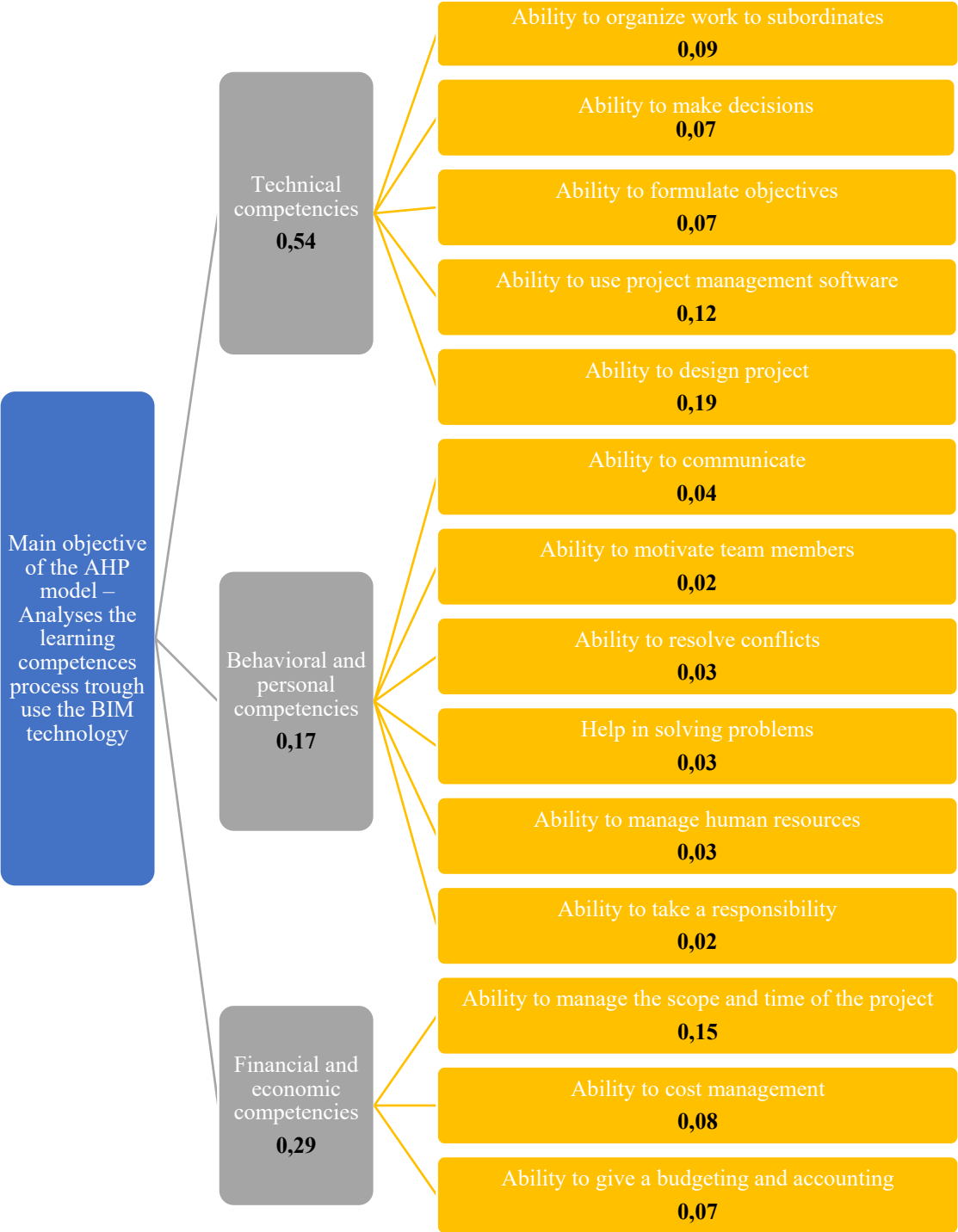


Figure 1. The learning competencies model through BIM technology (source: own processing)

#### 4. Conclusion

Construction project management is difficult and knowledge-requirement processes. Project managers present important issue of construction project management. Project managers do difficult decisions. Currently, digital age is thankful space for implementation of

technology that helps to the management processes. BIM technology presents one of them. BIM technology can be considered as one of the most effective and powerful tool in construction project management. BIM is not only 3D modeling. BIM and knowledge technology present very powerful tool in each stage of construction project. It's tool for the learning competencies too. Project managers achieved and development their skills through new technology as BIM tool too. Research shown importance of BIM technology in the learning competencies process. The most effective for project managers, it's the learning technical competencies. This study pointed to results predominantly from one area. Future research should address country differences. It may be interesting to see the differences between the perception of competencies of managers from different countries. Comparing several construction markets can be a space for further international research that could bring other important results.

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# Development of the Individual Competences in Construction Project Management: The Educational Approach

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## Abstract:

The paper considers a competency scheme that helps to manage educational construction projects with the use of new technology such as BIM. The first chapter describes the International Project Management Association (IPMA) Individual Competence Baseline. The IPMA standard is also a basis for the IPMA-Student educational program, which aims to increase students' competences in project management. Next part of the paper consists of the characteristics of the BIM educational project that is held by Warsaw University of Technology and is a practical preparation for work as professionals on BIM projects. The last part of the paper describes the competence scheme and its influence on work with the educational BIM projects. Specific definitions have been described, as well as activities or behaviors that have appeared in these projects. The overall aim of the paper is to examine the possibility and to show an impact of transferring the best-practices from IPMA Competence Baseline to the BIM educational projects. The research shows that students - after completing all project tasks within BIM educational framework, gain new individual competences, also in project management following IPMA competence standard model.

**Keywords:** *competences; project management; certification; student competences; BIM;*

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## 1. Introduction

The concept of competence has been repeatedly defined. There are many definitions of competences. Most of them refer mainly to the issues related to the effectiveness of the use of human capital of the organization, defining competences as the basis for the management of human resources. R. Boyatzis (1982) defines competences as the dispositions of a given person, which leads to behaviors consistent with the requirements of the workplace. On the basis of considerations concerning the definition of the term "competence", G. Filipowicz (Filipowicz, 2016, p. 46) proposes the adoption of a universal understanding of competence as "a disposition in the field of knowledge, skills and attitudes allowing for the implementation of professional tasks at the appropriate level". The IPMA Competence Baseline (ICB) indicates which competences are necessary for an individual project team member to finish a project with success. The set of competences will be different depending on the project specificity and the role taken by team member. Construction projects require knowledge and skills in architecture, civil engineering, electric systems engineering, etc., but also in project management.

The new educational approach brings students an opportunity to work in multidisciplinary teams. The growing tendency to exchange knowledge between industries with the project

management support (as for example digital project management tools) is a strong tendency not only in professional work but also in high-education. Interdisciplinary educational projects are initiatives of the university faculties or of the innovation hubs created for this purpose. One of the most famous structure that allows students to work on multidisciplinary projects using creative design techniques is Design Factory Global Network consisted of 21 Design Factories located on 5 continents ([www.dfgn.org](http://www.dfgn.org)). The participation of students in the multidisciplinary teams is often an operational purpose of the universities development strategy. The educational construction project described in this paper is an example of academic initiative that brings students a new experience and delivers new competences also in project management.

## 2. IPMA Individual Competence Baseline

In 2015 IPMA introduced the new version of global standard that has its basis on PMI methodology (IPMA, 2015). It was a response for the rapidly changing environment – “The professionals of tomorrow will work in distributed environments with overlapping and often conflicting stakeholder interests” (IPMA, 2015, p. 5). In the competence definition given by IPMA, three key components are crucial: knowledge, skills and abilities. Knowledge as a first key component of the competence model can be divided into declarative knowledge and procedural knowledge. Declarative knowledge consists of facts, people and situations, while procedural knowledge is a knowledge of procedures, techniques and problem solving. The second component are skills, that mean ability to use the knowledge in practice, i.e. to apply it in specific situations in a fluent and flexible way ensuring achievement of the assumed goal. The third component of the model determines the maintenance of behaviors resulting from knowledge and skills. Attitudes activate mechanisms responsible for initiating, directing and maintaining actions. Figure 1 shows the relation between competence components.

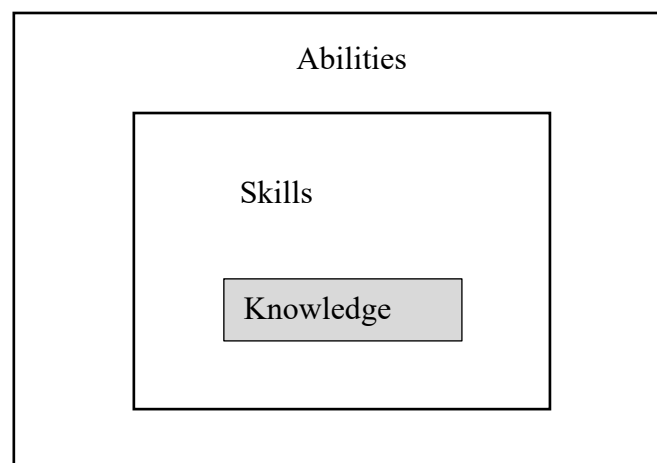


Figure 1. Relation between knowledge, skills and abilities (source: IPMA, 2015)

IPMA Competence Baseline (ICB) indicates which individual competences are necessary for effective project implementation. They were divided into three groups: technical, behavioral and contextual competences. The area of technical competence includes the basic elements of competence in project management, which are at the core of professional project management, sometimes referred to as "hard" elements. Behavioral competence area includes personal

competence elements in project management as the attitude and behavior of a project manager, its elements are sometimes referred to as “soft”. Contextual competence area includes elements related to the project context, concerning organization’s strategy, the relationship between the project and operational activity, the relationship of the project manager and the project management team with the line management and business management of the organization and to functioning within a 3P-oriented organization.

The new version of IPMA Individual Competence Baseline distinguishes 3 competence areas: people, practice and perspective. The first group of competences defines the personal and interpersonal competences required to succeed in 3P (projects, programme and portfolios) (IPMA, 2015, p. 5). The second one - defines the technical aspects of managing 3P. Competences of the “Perspective” group define the contextual skills and knowledge that must be navigated within and across the broader environment (IPMA, 2015, p. 5). IPMA Individual Competence Baseline is a general model that can be used in all sectors and industries. This means that appropriate methods, techniques and tools can be defined by the organization itself and the individual should select the appropriate components to suit the specific situation. The development of project management competence is also visible through the growing number of certified project managers. Among the various institutions involved in project management certification in Poland, IPMA is an organization that proposes a competence certification for project managers in four levels: Certified Projects Director – IPMA Level A, Certified Senior Project Manager – IPMA Level B, Certified Project Manager – IPMA Level C and Certified Project Management Associate – IPMA Level D.

The relation between competences and effectiveness of the company's activity was emphasized in most of the papers devoted to competence research. This results primarily from the relationship between the level of competence of the employee and the efficiency and effectiveness of tasks. In Poland a research conducted under the title of Human Capital Balance indicated that employers most often look for employees who have (PARP, 2015):

- professional competences relating to specific skills required to carry out tasks in a specific position
- competence in planning, self-organization, and especially in diligence, meticulousness and responsibility
- interpersonal skills, with particular emphasis on ease of contact, teamwork and communication

The result of the research still inspires universities to educate and prepare students to enter the labor market. IPMA indicates various approaches to the development of individual competences: self-development, peer-development, education and training, coaching and mentoring, simulation and gaming (IPMA, 2015, p. 20). Competence development by educational and training could be implemented by attending seminars, lectures and other educational projects. In 2014, IPMA together with the scientific and business community developed the IPMA-Student competence model. The model is dedicated to students and graduates of universities as a response to the growing interest of entrepreneurs in employees with project management competences in the labor market. There are three competence areas (same as in ICB): knowledge, skills and abilities. All of them are listed in table (Table 1) below.

Table 1. Student's competences in IPMA-Student model (source: IPMA ISEK matrix)

KNOWLEDGE	SKILLS	ABILITIES
K1. Recognizes and describes the place and role of project management in the organization management	S1. Monitors, analyzes and assesses the project's environment and stakeholders and takes it into account in the project's plans	A1. Thoughts and works in a systematic, creative and entrepreneurial way
K2. Characterizes and classifies projects, programs, project portfolios	S2. Properly recognizes and operates in the constraints resulting from the relationship between the permanent structure of the organization and the design structures	A2. Is oriented to real needs, goals and results
K3. Defines the criteria for project success and project management success	S3. Verifies the project goals and agrees with the business owner of the project	A3. Understands and accepts working conditions in projects
K4. Lists and characterizes the leading project management methodologies. Distinguishes the classic and agile project management approach	S4. Prepares project scope declaration and work breakdown structure (WBS)	A4. Is ready to operate in conditions of uncertainty and risk
K5. Names and describes the basic areas and elements of project management	S5. Plans the life cycle of the project according to the specifics of the project and the requirements of the business owner	A5. Takes responsibility for decisions and actions taken
K6. Recognizes and describes the basic methods, techniques and models of classical project management	S6. Prepares, presents and justifies the preliminary project plan	A6. Communicates with the environment
K7. Describes project management concepts by measuring performance and through exceptions	S7. Develop project schedules in accordance with best practices, including the critical path method (CPM)	A7. Is open to ideas, dialogue and seeks a consensus
K8. Identifies and describes the processes of pre-planning (initialization) and detailed (refinement) projects	S8. Estimates the demand for resources, identifies and solves resource overload problems	A8. Understands and appreciates personal, organizational and social values
K9. Indicates and describes the problems of project team management	S9. Identifies and evaluates qualitatively and plans reactions to risks in the project	A9. Acts in accordance with the applicable legal regulations and ethical norms within the designated organizational and social roles
K10. Lists and describes the key competences of the project manager. Recognizes the competence requirements of leading certification systems	S10. Develops the project budget using the right techniques for classifying and estimating costs	A10. Is aware of the need for independent, continuous improvement of knowledge and skills
	S11. Takes into account the quality expectations of the client in the project plan, works in accordance with the principles of quality	
	S12. Organizes the change management process in the project, analyzes and estimates the impact of changes on the project parameters	
	S13. Plans communication in the project and operates in accordance with the principles of effective and efficient communication	

	S14. Integrates information on various areas of project management	
	S15. Unambiguously defines the roles in the project team, assigns tasks including technical and psycho-social competences	
	S16. Organizes efficient and effective work of the project team	
	S17. Directs the work of the project team by choosing the right management style	
	S18. Identifies and explains the status of the project and forecasts the final result of the project according to the EVMS standard for various event scenarios	
	S19. Identifies, diagnoses and solves basic design problems using creative techniques	
	S20. Uses the project management documentation, correctly interprets and critically evaluates its records	

The certification IPMA-Student confirms the competences of a person who has gained the knowledge that can be applied at work as a beginner member of the project team. Such a person understands the project language, has the basic knowledge in particular areas of competences in project management, but does not have a professional experience yet. In other words, it is a person who has "instructions" to perform project tasks, but still needs a support in using appropriate techniques and methods in specific project conditions.

### 3. Educational BIM project: characteristics, competences and achievements

The growing importance of projects determines the growing demand for professional project knowledge (Trocki, 2014, p. 39) and competences related to project management, determining their effective implementation, and consequently the implementation of the organization's strategic objectives. Following R. K. Wysocki, project is “a sequence of unique, complex, and connected activities that have one goal or purpose and that must be completed by a specific time, within budget, and according to specification” (Wysocki, 2013, p. 4). PMI defines project as “a temporary endeavor undertaken to create a unique product or service” (PMI, 2000). The term "educational project" is often identified with the tasks that are obligatory in the school education. However, the term "project" was used for the first time in the 16th century at the Accademia di San Luca in Rome and meant practical exercises carried out by students of architecture (Lukehart, 2009). Students attempted to solve practical problems, which usually required the use of interdisciplinary knowledge. At the end of the 18th century, that project method has been widely used in technical and industrial universities in France, Germany and the United States. Therefore, the term “educational project” (in the higher education context) could be describes as unique, complex and risk-imposed set of connected activities, that has special methods of planning and implementation, must be finish by a specific time, requires the involvement of a variety resources, and is implemented by an

interdisciplinary team to achieve scientific results. Due to the specificity of the educational project, executed as part of wider educational programs, the project risk is usually low.

A specific feature of educational projects is its interdisciplinarity. The organization of work in interdisciplinary project teams requires flexible adjustment of knowledge and skills coming from various industries. To improve communication, this work is more and more often remote and takes the form of network cooperation, which makes it independent of location. Network cooperation brings an advantage in the following areas: communication, knowledge exchange, flexibility, innovation and relationships building. Last years showed that networking has been also adapted by science institutions as a result of changes in the processes of cooperation (more research: Sobolewska and Waszkiewicz, 2017).

The term “Building Information Modeling” - BIM can be understood as object information modeling and means the use of virtual models containing building information for the needs of design, documentation and analysis of building processes (Kivits and Furneaux, 2013). BIM has the characteristics of interdisciplinarity, because it combines technical, legal and organizational elements and allows to perform tasks dedicated to different professions – architects, civil engineers, electric engineers, etc. almost at the same time. BIM assumes simultaneous work by providing interoperable IT solutions. In the literature BIM is presented as a combination of two ideas: keeping digital project information in one place and parametric building modeling in real time in correlation with current data on the designed object (Tomana, 2016).

BIM approach in educational projects appeared at the Warsaw University of Technology in 2017 during the first edition of the project called “mpiBIM”. Representatives of 5 industries were involved: architects, civil engineers, hydrotechnics and environmental protection engineers, electrical installation engineers and management representatives. Project teams were supported by coordinators (academic teachers coming from 5 faculties) and business partners. The main purpose of this project, which has now its third edition, is to prepare complex building project in the form of BIM models. BIM technology supports engineers in three areas: providing alternative solutions, providing detailed information about the designed object and providing integration of the measurement data coming from different sources (Eastman *et al.*, 2011). The work of interdisciplinary teams (each counted 6-10 students coming from different faculties) is performed with the agile project management approach. Students have formal meetings once a week when they exchange information about project progress, deliverables and issues. All comments are reported in the standard report forms. Daily communication (via e-mail or Slack) allows management students monitor the project milestones and support the team members with other back-up tasks. The Must Finish-by date is also known at the beginning of the project and indicate the date when the project result is presented for the wide audience (Rector, Vice-rectors, Deans of the faculties, strategic business partners, media and other guests). mpiBIM also adopts Project Based Learning - PBL findings, which is a method that supports transfer of knowledge through its application in practice (e.g. prototyping) that results in delivering of the final product. Scientists indicate that the introduction of such a teaching method at the university level can bring positive results (Spatek, 2014). Inductive methods, such as PBL, force students to actively participate in classes and encourage project teams to work during work

meetings (not only held in the classroom) (Prince and Felder, 2006). The duration of the second edition of mpiBIM was 105 days (15 sprints). Students worked on 5 projects that were located on the main WUT Campus: Civil Engineering Faculty Building (2 alternative versions), Office Building, Administration Building and Conference Center. The purpose of the Project 1 and Project 2 was to design a complex Civil Engineering Faculty Building that combines lecture halls with laboratories and provides space for the Faculty’s staff. Project 1 has a specific design that shows two connected buildings surrounding the inner courtyard. An internal hall with a curtain wall on the entire height of the building is a central point of the project. Project 2 assumes that the building will be divided into 3 parts with the specific glass passages between them. Office Building (called by the team as “Campus Office”) delivers a modern and sustainable office space spread over 12 floors. The façade was made of a glass fiber membrane, suspended on a steel structure on the top 10 floors. Administration Building was designed as green building – with the wide atrium with plants, extensive green roof and an experimental green wall. The last project assumed to use modern art in the project design, therefore the middle object of the building has an interesting “egg” shape, but it is surrounded by the cover that gives the visual effect (especially at night), helps to secure construction of the middle part and provides smaller conference halls. The figures below (Figures 1-5) show selected student’s project results.

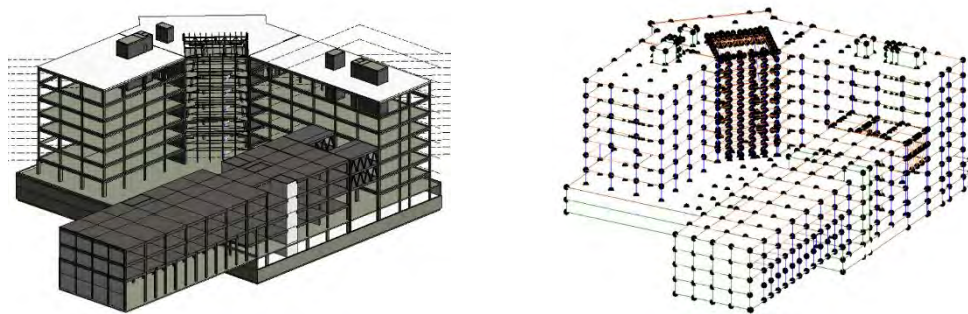


Figure 1. Construction of WUT Civil Engineering Faculty Building version 1 – Project 1 (source: Team 1 work on mpiBIM project at WUT)

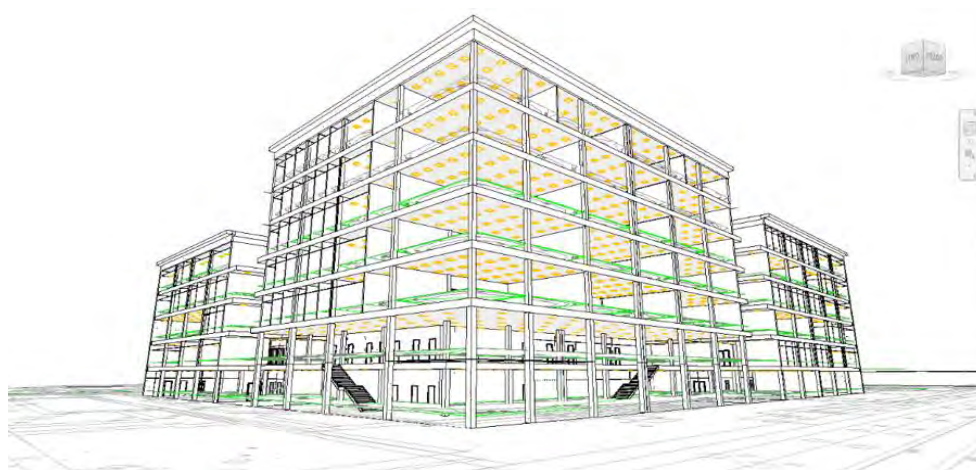


Figure 2. Construction of WUT Civil Engineering Faculty Building version 2 – Project 2 (source: Team 2 work on mpiBIM project at WUT)

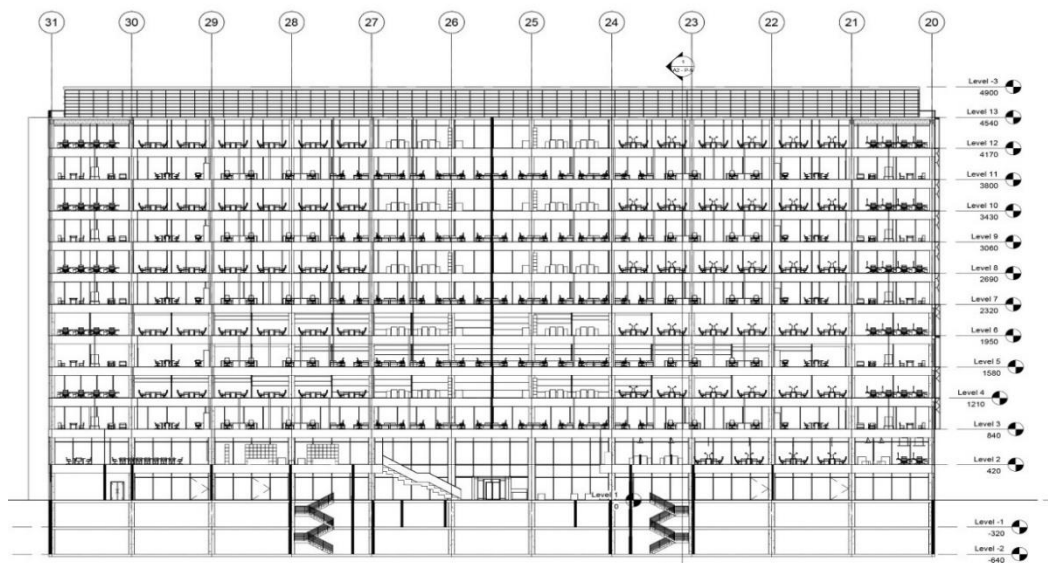


Figure 3. Office Building – Project 3 (source: Team 3 work on mpiBIM project at WUT)

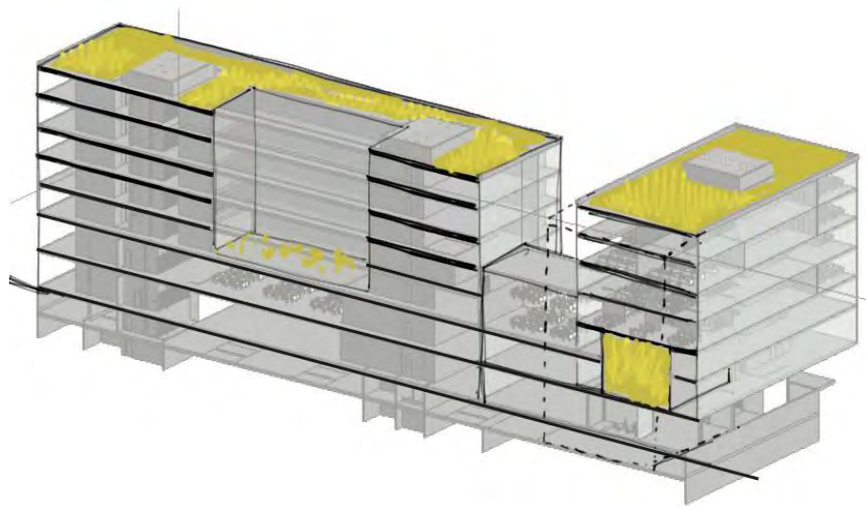


Figure 4. Administration Building – Project 4 (source: Team 4 work on mpiBIM project at WUT)



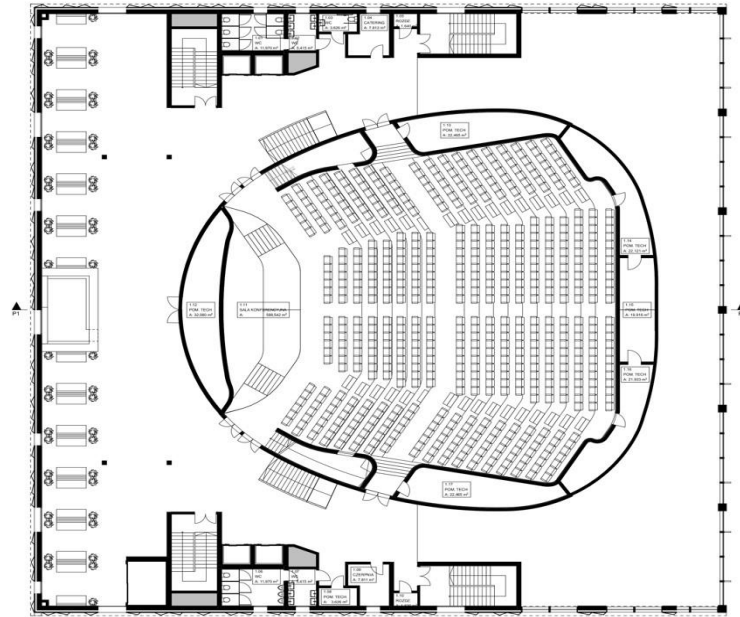


Figure 5. Conference Center – Project 5 (source: Team 5 work on mpiBIM project at WUT)

Students who took part in the “mpiBIM” project had an opportunity to gain a new, unique experience by working together in interdisciplinary team. Through informal and formal meetings, they had a chance to get to know competences from other industry. Therefore, they also gained new knowledge, skills and abilities.

#### 4. Increase of project management competences

To find out more about an increment of individual competences gained by the participation in the educational BIM project, a survey was conducted among all project participants. 54 students have been examined with the questions about knowledge, skills and abilities they have had before and after project. For the question “What prompted you to take part in the project?”, most of the respondents answered that the key reason was acquiring the skills of team-working (64,8%). Other answers referred to willingness to enrich knowledge about own industry (14,8%) and willingness to gain knowledge from other industries (3%). The second question concerned the knowledge about BIM approach before the start of the project. Results are presented on Figure 6.

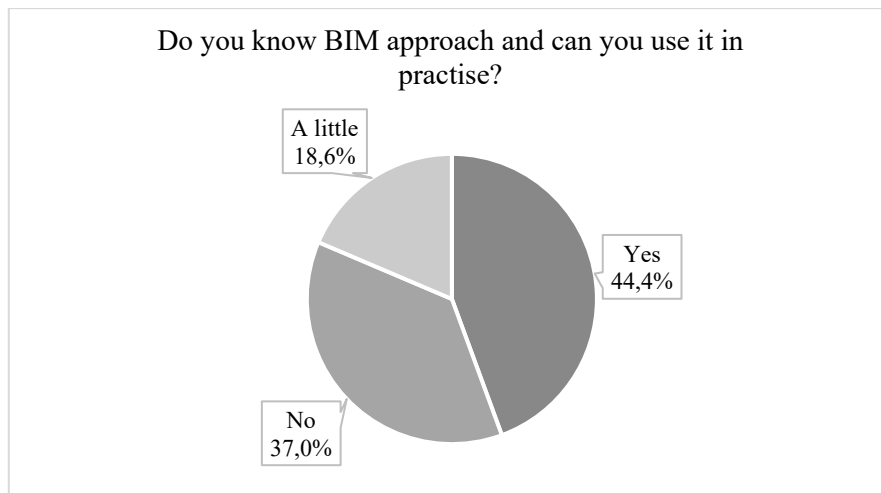


Figure 6. The student's knowledge of BIM before the project start (source: own research)

Before the project started, students have been aware of possibilities that BIM brings to the design of buildings, but some of them have not recognized this approach. 10 students (19%) have heard about BIM but had some problems to use it in practise.

Next question concerned the knowledge about BIM approach after the finish of the project. Results are presented on Figure 7.

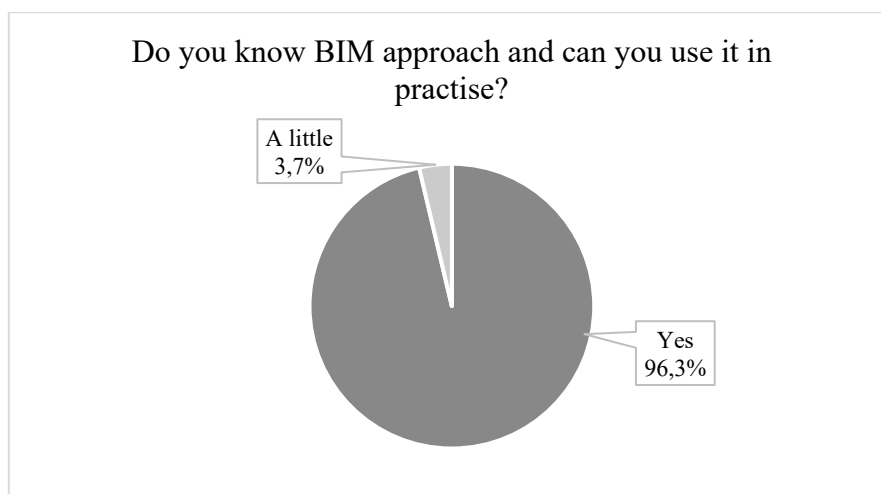


Figure 7. The student's knowledge of BIM after the project finish (source: own research)

Almost all students after the completion of the project gained knowledge, skills and abilities in application of BIM approach in building design. All team members had an opportunity to work with *.ifc* files that are the common files containing complex information about the designed building. They have also become familiar with AutoCAD, REVIT and ArchiCAD solutions.

The questionnaire concerned the questions about competences in project management. Students could answer an open-questions about knowledge, skills and abilities they gained during the project. Responses varied widely. Some of them pointed out the team-management skills. Others noticed that "mpiBIM" project provides a lot of practical knowledge and helps to gain interdisciplinary experience. There was an answer that BIM project verified the knowledge

acquired during studies. Respondents indicated a role of the effective communication by using common communication tools (as Messenger) and dedicated solutions (as BIM Track). Considering the IPMA model that presents competences in 3 categories, the summary review of the answers given by the individual team members is presented in Table 2.

Table 2. Student’s competences after mpiBIM project based on in IPMA-Student model (source: own research)

KNOWLEDGE		SKILLS		ABILITIES	
K1.	X	S1.		A1.	X
K2.	X	S2.	X	A2.	X
K3.	X	S3.	X	A3.	X
K4.	X	S4.	X	A4.	X
K5.	X	S5.		A5.	
K6.		S6.	X	A6.	X
K7.		S7.	X	A7.	X
K8.	X	S8.	X	A8.	
K9.	X	S9.	X	A9.	X
K10.		S10.	X	A10.	X
		S11.			
		S12.	X		
		S13.	X		
		S14.	X		
		S15.	X		
		S16.	X		
		S17.			
		S18.			
		S19.	X		
		S20.	X		

Results presented above indicate the need to introduce innovative, interdisciplinary educational projects to the university's programs. During 105 days of intensive work, students were able to present a complex building model containing all installations with relevant calculations. They worked in teams that had issues, but they shared one goal – to design a modern, complex and BIM-oriented building by the synergy effect that was possible by the combination the knowledge, skills and abilities in one team. Additionally, they had an opportunity to meet project management methodologies, approaches and tools.

## 5. Conclusions

“mpiBIM” project is an educational initiative of Warsaw University of Technology. It assumes that students will work in interdisciplinary teams and will represent a set of competences from their industries. During project work they get familiar with the specifics of all the industries involved, they gain new knowledge, skills and abilities. This experience brings

them an opportunity to gain competences in project management, which are especially desirable in construction projects. These competences can be divided into 3 groups following the IPMA Individual Competence Baseline (ICB). The research shows that working together within interdisciplinary team brings new achievements in these 3 areas as e.g. identification and ability to describe the processes of pre-planning (initialization) and detailed (refinement) projects, indication and ability to describe the problems of project team management, preparation of project scope and Work Breakdown Structure, developing project schedules in accordance with best practices, including the Critical Path Method or getting ready to operate in conditions of uncertainty and risk. The described BIM project increased project management competences not only of students that study management sciences, but also to future engineers, that now can lead their projects using the PM methodologies, approaches or tools.

The team-members gained new competences described in ICB, but not all of them. The IPMA-Student certification is a good way to assess a complex knowledge, skills and abilities that is useful for beginner members of project team. It is a perfect solution for engineers that will become specialists in their industries, but also need to follow the actual achievements in project management.

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# Influence of Innovative Orientation on Small and Medium Construction Enterprises in Nigeria

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## Abstract:

Small and medium construction enterprises (SMCEs) are known to play an important role in stimulating economic development and employment generation. The input of SMCEs especially in developing countries is however, most often restricted because of their low capacity and poor performance. Entrepreneurship orientation (EO) which reflects the tendencies of firms to act entrepreneurially is regarded as a catalyst for improving firm performance in the current business environment. This paper investigated the level of adoption of innovativeness dimension of EO and its influence on financial performance of SMCEs in Nigeria. A quantitative approach was adopted to obtain data from a sample of 139 owners and top managers of Nigerian SMCEs through a cross sectional questionnaire survey strategy. SPSS and Structural Equation Modeling (SEM) using SMARTPLS 3.0 were employed to analyze and test the hypothesized relationship between innovativeness and financial performance of SMCEs in the study. Findings revealed a significant level of adoption of EO dimension of innovativeness by SMCEs in the study. A positive and significant relationship was also established between innovativeness and financial performance of the SMCEs. The study concludes that SMCEs benefit positively by adopting an innovative posture in their business decisions.

*Keywords: entrepreneurship orientation; innovativeness; financial performance; small and medium construction enterprises (SMCEs)*

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## 1. Introduction

Most organizations including those in the construction sector are facing increasing competition due to the rapidly changing business environment. Consequently, firms are being compelled to respond by adopting best business practices in order to remain relevant in their domains (Al Swidi and Al Hosam 2012). Scholars have identified entrepreneurship as one important business strategy for improving the competitive standing of firms in different economic sectors (Oteh, 2009; Makhura, 2011, Abd-Hamid *et al.*, 2015). Entrepreneurship orientation (EO) which reflects the processes, methods and styles that organizations use to act entrepreneurially have attracted the attention of researchers because of its reported positive influence on firm performance (Rauch *et al.*, 2009; Zainol and Ayadurai, 2011; Arshad *et al.*,

2014). EO has been characterized with five key dimensions: innovativeness, risk-taking, proactiveness, autonomy and competitive aggressiveness with each dimension influencing performance depending on the context (Lumpkin and Dess, 2001; Rauch *et al.*, 2009; Dafel, 2012; Arshad *et al.*, 2014).

Despite its competitive landscape, it has been observed that the construction industry especially in developing countries have not enjoyed serious attention from EO scholars (Zain and Hassan, 2007; Abd Hamid *et al.*, 2015). Hence; there is paucity of empirical data on the entrepreneurial posture of firms in this important sector. The current paper is focused on investigating the level of adoption of innovativeness dimension of EO and its influence on firm performance in the context of small and medium size construction enterprises (SMCEs) in Nigeria. The particular focus on SMCEs was in view of their generally acknowledged contribution to economic growth and employment generation. Moreover, studies have shown that in both developed and developing countries, small and usually specialized firms form a large part of the construction industry (Moavenzadeh, 1976; Idiake and Bala, 2012; Odediran *et al.*, 2012). The input of SMCEs especially in developing countries is however, most often restricted because of their low capacity and poor performance. Hence any research effort aimed at improving the performance of these categories of firms will have an overall beneficial effect on the economy.

### *1.1 Innovativeness*

Innovativeness reflects the tendency of firms to engage in and support new ideas, novelty, experimentation and creative processes resulting in newness (Arshad *et al.*, 2013). It is an EO dimension that is considered a necessity for an entrepreneurial organization. According to Lumpkin and Dess (1996) innovativeness is a key component of EO because it reflects important means by which firms pursue new opportunities. Whether they are building new firms or reinventing existing ones, entrepreneurs apply new ideas to products and services to capture market opportunities. In the organizational context, innovation can happen to products, processes, or services and may refer to technology or method that is currently within the realm of existing practices but is just new to the organization adopting it (Gambatese and Hallowell, 2011). In the construction industry context, *product innovation* may involve the application of new construction materials/components that generates new and significantly improved value to a building (Kim and Reinschmidt, 2011; Mohammad *et al.*, 2014). *Process innovation* is concerned with the implementation of a new or significantly improved production or delivery method. This may include significant changes in techniques, equipment and/or software. Examples of process innovation in construction include the new systems buildings such as BIM, IBM; others may include modern procurement systems such as project management and public-private partnership (Mohammad *et al.*, 2014). *Marketing innovation* refers to the introduction of new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing. *Organisational innovations* signify the introduction of a new organisational method in the firm's business practices, workplace organisation or its external relations (Ozorhon *et al.*, 2010; Mohammad *et al.*, 2014). It may involve changes to the organization structure, introduction of advanced management techniques, and implementation of new corporate strategy orientations (Mohammad *et al.*, 2014).

Researchers and scholars have long identified innovation as an important strategy for the survival of organizations in a dynamic environment like the construction industry (Manley and McFallen, 2006; Gambatese and Hallowell, 2011; Yusof *et al.*, 2015, Mohammed *et al.*, 2014). Unfortunately, one of the charges leveled against the construction industry is that of poor record on innovation, especially when compared to industries such as manufacturing (Ozorhon *et al.*, 2010; Mohammed *et al.*, 2014). According to Tangkar and Arditi, (2004) studies have shown that the innovation mindset of the construction industry is very conservative. It was however, argued by Loosemore, (2015) that while the construction sector is often derided for being a low innovation industry, the reality is that it is a highly creative industry that is adept at solving complex operational problems on a project-by-project basis. This view was echoed by Ozorhon *et al.*, (2010) when they observed that much of the innovation in the construction sector occurs at the project level and tends to be process and organization based innovations that are not easily measured by conventional measures of innovation such as research and development. According to Gambatese and Hallowell (2011) innovation in the construction industry may take place at a lower rate compared to other industries due to the structure and characteristics of the industry and projects, but it does, and must, occur in a competitive market as all companies do innovate at some level in order to stay competitive. In view of the above, the current study postulates that:

**H<sub>1</sub>:** There is a significant level of adoption of innovativeness dimension of EO among SMCEs in Nigeria.

### 1.2 *Innovativeness and firm performance*

A large amount of empirical literature have reported a positive relationship between innovativeness and firm performance (Zahra and Bogner, 2000; Rauch *et al.*, 2009; Casillas and Moreno, 2010; Ambad and Wahab, 2013; Arshad *et al.*, 2013; Magaji *et al.*, 2014). In a study of 116 US based software firms, Zahra and Bogner (2000) reported that an increased innovation in new ventures results to higher performance of firms in the study. An empirical research among SMEs in Spain by Casillas and Moreno (2010) found that innovativeness and firms' growth in terms of sales, assets, and employment growth are positively correlated. A similar study among Taiwanese SMEs in China also reported that innovativeness correlates positively with firm performance (Wang and Yen, 2012). Arshad *et al.* (2013) and Magaji *et al.* (2015) have both reported positive influence of innovativeness on the performance of SMEs in Malaysia and Nigeria respectively. Some few studies such as Kusumawardhani (2013) and Okangi and Letmathe (2015) however, fail to establish correlation between innovativeness and financial performance of firms. According to Rauch *et al.* (2009) an innovative strategic posture should have a positive impact on firm performance by capitalizing on emerging-market opportunities. In view of the reported diverse findings on the relationship between innovativeness and firm performance, this study hypothesized that:

**H<sub>2</sub>:** There is a significant relationship between the innovativeness dimension of EO and financial performance of SMCEs in Nigeria.



## 2. Data Collection and Methods

A cross sectional field survey strategy with the aid of structured questionnaires was employed as the tool for data collection in this study. The targeted population of the study were Owners/CEOs and top-level managers of construction firms operating in Lagos and Abuja, Nigeria. The choice of these locations was in view of their strategic importance to Nigeria and their being hosts to a large number of construction firms. Lagos is Nigeria's economic nerve centre while Abuja is the administrative headquarters of the country. Previous studies such as Adams (1997) and Adeleke *et al.*, (2017) have used these locations to base their analysis of construction firms in Nigeria for similar reasons. The list and addresses of construction firms on the database of the Federal Inland Revenue Service (FIRS) provided the sampling frame for the study. This database was considered credible because it captures firms that regularly pay taxes to the government. A total of 9,128 firms (5,124 in Lagos and 4,004 in Abuja) were registered on the database as at January 2017. Simple random sampling technique was used to select samples with the sample size selection guided by Krejcie & Morgan (1970) table. For a total sampling frame of 9,128 firms, the appropriate sample size suggested by the table was 370. Hence 370 questionnaires were distributed to respondents in the study. Although the questionnaire was administered to all categories of firms in the database, however, only the results for firms categorized as small and medium construction enterprises (SMCEs) were utilized for analysis in the study. The study adopted the number of permanent employee's criteria as the basis for categorizing SMCEs where only firms employing less than 200 workers were considered. This was in accordance with the SMEDAN/NBS (2013) definition of SMEs in Nigeria. Most researchers according to Curran and Blackburn (2001) prefer using the number of employees to define SMEs because it is an objective measurement that is easier to obtain from firms than financial information. The questionnaires were self-administered by the researcher and other research assistants in the study area. Out of the 370 questionnaires distributed about 139 were returned valid and suitable for analysis. This represents 37.6% response rate in the study.

### 2.1 Variables and measurements

The measures of innovativeness which represents the independent variable in the study was adopted from previous studies such as Lumpkin and Dess (1996), Dafel (2012) and Okangi and Lethmathe, (2015) with slight modifications to suit the context of the construction industry. The scale contains 6 subjective statements measuring the innovative proclivity of respondents in their business operations. The respondents were requested to indicate the extent of their agreement or disagreement with each statement on a five point Likert scale with "1=strongly disagree" and "5=strongly agree". Financial performance was measured using subjective indicators of profitability and growth. The measures were developed from ideas and suggestions of previous studies such as Zulkifli and Perera (2011), Santos and Brito (2012) and Selvam *et al.*, (2016). The preference for using subjective measures was in recognition of the difficulties in obtaining objective financial data from businesses. Most firms often refuse to disclose accurate, objective data and even where such is made available; managers tend to manipulate such data to avoid issues such as taxes (Zulkifli & Perera, 2011). Profitability and growth indicators were represented by seven items namely: return on investment (*FNPI*), return on

asset (*FNP2*), general profit (*FNP3*), growth in assets (*FNP4*), growth in market share (*FNP5*), growth in number of employees (*FNP6*) and growth in revenue (*FNP7*). Respondents in the study were requested to subjectively assess the performance of their firms over the last three years relative to other competitors on a 5-point Likert scale with “1= very low performance” and “5= very high performance”. Data obtained in the study was analyzed with the aid of SPSS version 20.0 and SmartPLS version 3.0 softwares. SPSS was used for descriptive statistics and one sample t-test while SmartPLS was used to conduct Structural Equation Modeling (SEM) in order to test the hypothesized relationship between the constructs in the study.

### 3. Results

Table 1 and two 2 presents the mean values and one sample t-test result for innovativeness. The innovativeness scale which consists of statements coded *INN 1-6* has mean values ranging between 2.352 to 3.863 with a total average mean score of 3.388. Result for individual indicators shows that *INN2* (Mean= 3.863) was ranked 1<sup>st</sup> indicating that most respondents agrees that innovation is a necessity for the survival of their firms. An inclination towards creativity *INN5* (Mean = 3.856) and continuous improvement to products, services and processes *INN1* (Mean = 3.842) were ranked 2<sup>nd</sup> and 3<sup>rd</sup> by respondents. The result however indicates low proclivity toward investment in research and development as shown by the poor mean scored by statement *INN6* (Mean=2. 353) which ranked last among the indicators of innovativeness. The values for standard deviation across all the indicators were found to be low suggesting convergence of opinions across the study respondents on these indicators.

Table 1: Mean values for indicators of innovativeness.

Code	Indicators of Innovativeness	Mean	Std. Deviation	Ranking
INN1	Continuous improvement to products/ services	3.842	0.581	3
INN2	Innovation an absolute necessity for our firm	3.863	0.616	1
INN3	Changes in our products/services quite dramatic	3.036	0.685	5
INN4	Quick to use improved work methods	3.381	0.595	4
INN5	Creativity in our operations	3.856	0.620	2
INN6	Budget provision for research and development	2.353	0.824	6
	Average Total Mean	3.389		

Table 2: Result of one-sample test

Variable	T	Df	Test Value = 3		Mean Difference	95% Confidence Interval of the Difference	
			Sig. (2-tailed)	(2-Mean)		Lower	Upper
Innovativeness	9.617	138	.000	3.389	0.389	0.309	0.468

A one-sample t-test was carried out to test the level of significance of adoption of the innovative dimension among the sample of SMCEs in the study. A hypothesized mean value of 3.0 was used as a benchmark with the test set at 5% level of significance. Table 2 shows that, the mean test (3.389 ± 0.476) was higher than the hypothesized mean value of 3, a statistically significant difference of 0.389 (95% CI, 0.309 to 0.468),  $t(138) = 9.617, p = 0.000$ . Since the

$p$ -value is lower than 0.05, it was concluded that there was a significant level of adoption of the innovative dimension of EO among SMCEs in the study.

### 3.1 Relationship between innovativeness and financial performance

The hypothesized relationship between innovativeness and financial performance was examined through structural equation modeling (SEM) using SmartPLS 3.0 software. The model in figure 1 shows the direct relationship between the two constructs with the outer factor loadings, coefficient of determination ( $R^2$ ) and the path coefficient highlighted.

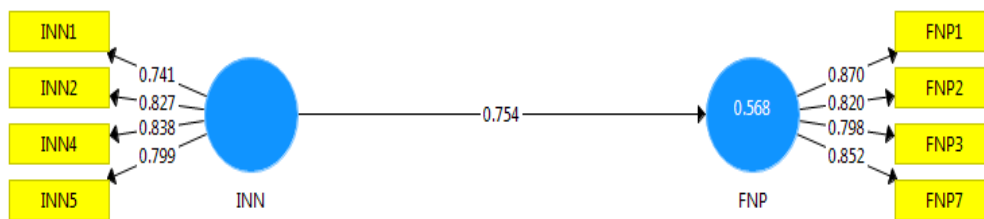


Figure 1: Direct relationship between innovativeness and financial performance

Legends: INN: Innovativeness, FNP: Financial performance.

Two items from the original six (6) on the innovative scale ( $INN3$  &  $INN6$ ) and three items from the financial performance scale ( $FNP4$ ,  $FNP5$  &  $FNP6$ ) were dropped for having factor loadings less than 0.7. The rule of thumb is that indicators with outer loadings less than 0.70 should be dropped to improve reliability and validity of measurement scales (Hair *et al.*, 2012). The first step in a PLS-SEM is to evaluate the measurement model by assessing the construct reliability and validity to ensure that the survey instrument used is reliable and valid.

#### 3.1.1 Construct reliability

Both Cronbach alpha and composite reliability measures were used to establish the internal consistency of the indicators used in the study. The composite reliability and Chronbach's alpha were extracted from the PLS-SEM algorithm. According to Hair Jr. *et al.* (2014) composite reliability and Chronbach's alpha values above 0.7 are considered reliable. Table 3 shows that the Chronbach's Alpha and Composite reliability figures for the two constructs are above 0.7. Hence, all values fall within the acceptable range to conclude that the measures used were reliable.

#### 3.1.2 Convergent validity

Construct validity involves the evaluation of the degree to which a construct correctly measures what it is supposed to measure (Hair *et al.*, 2012). The convergent validity of the scales in this study was assessed through the factor loadings and the Average Variance Extracted (AVE). According to Hair Jr *et al.* (2014) the factor loadings for measured indicators must exceed 0.70 while AVE values should be above 0.50 to confirm convergent validity of

measured constructs. Table 3 reveals that the factor loadings for all measured items are all above 0.7 while AVE values also exceed the 0.5 cut off point. This indicates that the convergent validity for the two constructs is also confirmed.

### 3.1.3. Discriminant validity

Table 4 shows the discriminant validity values for the two constructs in this study. Fornell and Larcker (1981) criterion requires the square root of AVE (*in bold*) for a construct to be greater than all correlations between that construct and other constructs. The result therefore indicates that discriminant validity was confirmed in the study.

Table 3: Internal consistency, construct reliability and convergent validity measures

Constructs/Items	Factor Loadings	Cronbach Alpha	Composite Reliability	Average Variance Extracted (AVE)
Innovativeness		0.815	0.878	0.644
INN1	0.741			
INN2	0.827			
INN4	0.838			
INN5	0.799			
Financial Performance		0.857	0.902	0.698
FNP1	0.870			
FNP2	0.820			
FNP3	0.798			
FNP7	0.852			

Table 4: Discriminant validity: Fornell-Larcker criterion

	FNP	INN
FNP	0.836	
INN	0.754	0.802

### 3.2 Assessment of structural inner model and hypothesis testing

After establishing the reliability and validity of the measurement scale, the next step was to test the hypothesized relationship between the study constructs. This was achieved through bootstrapping as required by the PLS-SEM algorithm (Wong, 2013). About 1000 bootstrapped samples were used to test the significance of the relationships between the two variables in the study. Empirical t-values higher than 1.96 are considered statistically significant (for 2-tailed test, at 5% level of significance). The bootstrap result as shown in table 5 reveals a positive and significant path coefficient between innovativeness and financial performance ( $\beta=0.754$ , t- value (20.308)>1.96). The findings suggest that innovativeness is statistically significantly related to financial performance of SMCEs in the study. The finding provides support for hypotheses **H2**.

Table 5: Inner Path Coefficient and Hypothesis Testing

Hypothesis	Relationship	Path coefficient	T Statistics	P Values
H2	Innovativeness -> Financial performance	0.754	20.308	0.000

#### 4. Discussion and Conclusion

The result clearly indicates that the sample of Nigerian SMCEs in the study have an overall positive inclination toward innovation in their businesses. The construction industry has severally been challenged to embrace innovation in order to improve its competitiveness and deliver better value for money to its clients (Latham, 1994; De Valence, 2010). Thus, the promotion and sustenance of innovation is considered a key area that must engage the attention of top managers of construction firms (Abd-Hamid *et al.*, 2015). It was therefore, not surprising that the sample of Nigerian SMCEs have shown tendency for acting innovatively. All the measured indicators of innovativeness with the exception of “budget provision for R&D” scored a mean above 3. The low mean scored by this indicator seems to suggest that although Nigerian SMCEs have shown propensity for acting innovatively, the willingness to commit resources to drive it through research was lacking in their innovative strategy. The low level of commitment to expenditure in R&D was found to be consistent with previous findings for firms in the construction sector (Egan, 1996, Kalatunga *et al.*, 2006, Littlemoore and Chan, 2009). Construction firms have consistently been referred to as innovation laggards especially when measured by indicators of R&D and patenting activities (Littlemoore and Chan, 2009; de Valence, 2010).

The findings also reveal a positive correlation between innovativeness and financial performance with 56.8% of the variance explained. This underscored the significance of innovativeness in predicting the financial performance of SMCEs. The result was found to be consistent with the findings of Arshad *et al.*, (2013) and Magaji *et al.* (2014) who reported a positive correlation between innovativeness and financial performance of SMEs in Malaysia and Nigeria respectively. Other previous studies such as Rauch *et al.*, (2009) and Ambad and Wahab (2013) have also established the relevance of innovativeness in improving financial performance of firms. The result was however, found to be in contrast with the findings of Okangi and Letmathe (2015) who reported lack of significant relationship between innovativeness and performance of Tanzanian construction firms. It was concluded from the study that majority of SMCEs in Nigeria have recognized and embraced the imperative of an innovative posture as an important business strategy in the construction sector. This was considered a positive development especially in the face of the alleged poor performance reported among construction firms in Nigeria. The positive correlation established between innovativeness and performance suggest that SMCEs can improve their financial objectives such as return on investment, return on asset, general profit and growth in revenue by acting innovatively. The study recommends the need for SMCEs to capitalize on innovative strategies in order to engender better performance in their business operations.

Despite its theoretical and empirical contributions to the current body of knowledge on the relationship between innovativeness and firm performance in the context of SMCEs, the

study has some limitations. One of these limitations concerns the use of perceptual rather than objective performance measures which may not necessarily provide accurate information on the actual performance of the surveyed firms. Another limitation relates to how financial performance indicators were treated as a single construct. This does not provide clearer and detailed information of the relationship between innovativeness and specific performance indicators (e.g. between innovativeness and return on investment or general profit).

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# Improving Competences of Engineers and Workers in the AEC Industry for Delivering NZEBs

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## Abstract:

The Energy Performance of Buildings Directive requires from the European Union Member States to ensure that by 31<sup>st</sup> of December 2020 all new buildings are Nearly Zero-Energy Buildings (NZEB) and after 31<sup>st</sup> of December 2018, new buildings occupied and owned by the public authorities should also have the NZEB performance. The large-scale deployment of NZEBs represents a challenge for all the stakeholders involved in the construction sector, where the lack of adequate competences is identified as one of the main obstacles. This paper analyses the current situation in the construction industry in Croatia and provides a possible solution for the abovementioned problem. Fit-to-NZEB and Net-UBIEP (Horizon 2020 projects) are dealing with the lack of education and competences in Architecture, Engineering and Construction (AEC) industry for delivering NZEBs. Fit-to-NZEB aims to increase knowledge of AEC engineers and workers in deep energy retrofit through the education in EQF levels 3-7, while Net-UBIEP seeks to develop the schemes for using Building Information Modelling (BIM) throughout the whole building lifecycle to increase building's energy performance. The integrated design process and strengthen control on the construction site, supported by BIM, should be carried out as they are the most critical parts in delivering NZEBs. Therefore, Fit-to-NZEB and Net-UBIEP projects can contribute to upgrading professional competences of all the stakeholders involved in the design and realisation of NZEBs.

**Keywords:** *education in construction; nearly zero-energy buildings; net-UBIEP; fit-to-NZEB; BIMzeED; building information modelling;*

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## 1. Introduction

To achieve 2020, 2030 and 2050 goals set by the European Union through the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED), a large scale of Deep Energy Retrofit (DER) should be carried out. EPBD prescribes that by 31<sup>st</sup> of December 2020 all new buildings and all the buildings under major renovation should perform as NZEBs. The same applies to the buildings occupied and owned by the public authorities after 31<sup>st</sup> of December 2018, because buildings owned and occupied by the public authorities should be a good-practice example as they are representing the state and therefore should adopt energy efficiency demands first to encourage others to follow their example. The EED also set strict energy-efficiency targets on European building stock with demand for every EU Member to develop a program for deep energy renovation of the building stock up to 2050. As a result of the deadlines mentioned above, it can be concluded that the large number of NZEBs will be built from now, up to 2050. A question which arises is, are the engineers and workers in the

Architecture, Engineering & Construction (AEC) industry well prepared to fulfil such a demand? This paper describes the current situation in the AEC industry concerning Deep Energy Retrofit (DER) in Croatia and tries to provide a possible solution for increasing the competences of the AEC stakeholders through European scientific projects.

DER could be a stabiliser for the building sector and consequently the overall EU economy (Saheb *et al.*, 2015) with necessary technological improvement and the innovations in the AEC industry to achieve the NZEB performance. The interdisciplinary approach in all the building lifecycle, as shown in Figure 42 (from the early planning phases through the construction, commissioning, operation & maintenance to the demolition and recycling), must be implemented for the same reason, as well as a digital transformation of the AEC processes. As one of enablers of interdisciplinary collaboration, Building Information Modelling (BIM) is therefore inevitable. BIM, integrated with energy performance requirements, can facilitate the improvement of building energy performance more effectively and efficiently. By achieving the NZEB performance, the society will benefit not only in the reduction of the energy demands but also in lowering the emission of the greenhouse gasses, and all of that should be followed by increased indoor comfort of occupants

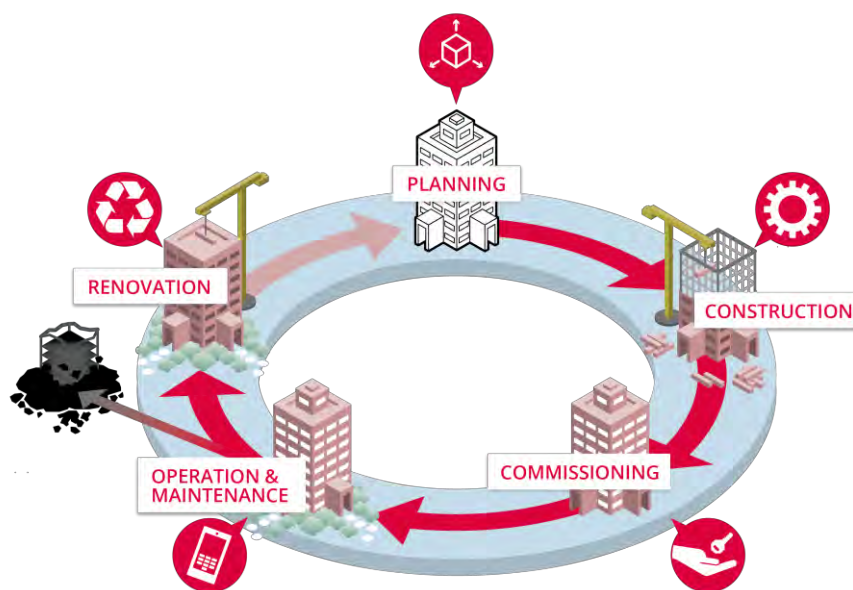
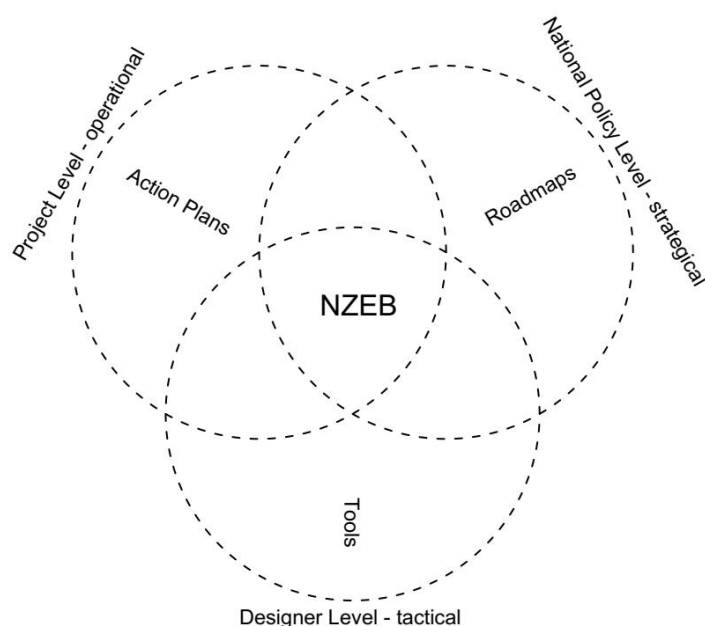


Figure 42. Building lifecycle (source: <https://hydraulic-flow-control.com/en/page/our-services--building-life-cycle>).

It can be concluded that the additional education in the field of NZEBs and BIM needs to provide the necessary technical knowledge to the public administration, engineers, architects, technical supervisors, and site managers, not excluding the other experts. At the moment of writing this paper, such education at the Universities in Croatia is being provided sporadically with a few courses concerning NZEBs and BIM, and those courses are also lacking an interdisciplinary approach. On the other hand, Life Long Learning (LLL) courses are sporadic and lack a systematic approach.

## 2. NZEB and BIM interdependence

The EPBD set out the definition for a building with nearly-zero energy consumption on the European level: “a building that has a very high energy performance” where “the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby (European Parliament and the Council of the European Union, 2010). Every EU Member State has created a definition of the NZEB, based on the abovementioned definition concerning the country’s economic and climatic conditions. The Croatian government also recognised the need to stimulate the AEC sector by introducing large scale renovation programmes (European Construction Sector Observatory, 2018). The government launched several financial support instruments and energy renovation programmes targeting family homes and multi-family housing, because the residential sector accounts for around one-third of total energy consumption and, therefore, has the highest energy saving potential (European Bank for Reconstruction and Development, 2017). Public and commercial buildings are also included in the supporting programs, as they should serve as an example to the other building owners. An ambitious project of the building stock renovation in Croatia is defined by the National Building Renovation Strategy (Republic of Croatia, Ministry of Construction and Physical Planning, 2017) which includes a plan (Republic of Croatia, Ministry of Construction and Physical Planning, 2014) for increasing the number of NZEBs up to 2020 as well. Up to the moment of writing this paper, a very few NZEBs were designed and built in Croatia, and by following scheme shown in Figure 43 (Attia, 2018), their number will increase.



**Figure 43. Three measures to accelerate the implementation of NZEB (Attia, 2018).**

Construction projects are managed mainly by small and medium-sized companies, but they have a limited ability to catch up with the massive flow of the information and knowledge available today. *Building energy use optimisation* requires an integrated design and interdisciplinary approach. This way will only lead to a high-quality indoor environment, and it will satisfy the occupants’ needs (Cromwijk *et al.*, 2017). An advanced NZEB design requires

practical and efficient information sharing among all the members from different disciplines in an Integrated Design Group (IDG) to make the decisions about selecting the right set of energy retrofit design options (Yang *et al.*, 2015). This advancement could be achieved by introducing Integrated Product Design (IPD) into the NZEB design process (Cromwijk *et al.*, 2017). It became clear that better information management during a lifecycle of an NZEB is necessary for avoiding mistakes and storing reliable information which can be achieved by BIM.

BIM model is a representation of the functional and physical characteristics of a building in a digital environment with information stored and attached to building elements stored as objects. That organised and shared information database about the facility is a regular basis for the decision-making process not only in the design and the construction phases but throughout whole building lifecycle as well.

All stakeholders in AEC industry and wider should be educated explicitly in an integrated design approach using BIM to increase the quality of both designed and built NZEBs. BIM is an excellent tool for designing NZEBs because more time is spent on the early planning and the design phase, therefore, a more advanced solution could be provided with the cost-optimality. The other main reason for using BIM as a tool for NZEB design, and managing building information, is that not only more variant solutions can be examined but also a preliminary energy simulation could check all of those solutions, so the quality of NZEB design increases drastically (Gumbarević *et al.*, 2019).

### **3. Methodology**

Improving competences in AEC industry should includes improving competences of all stakeholders, workers, professionals and engineers regarding NZEB and BIM.

This paper will present current situation in Croatia AEC industry from three important aspects:

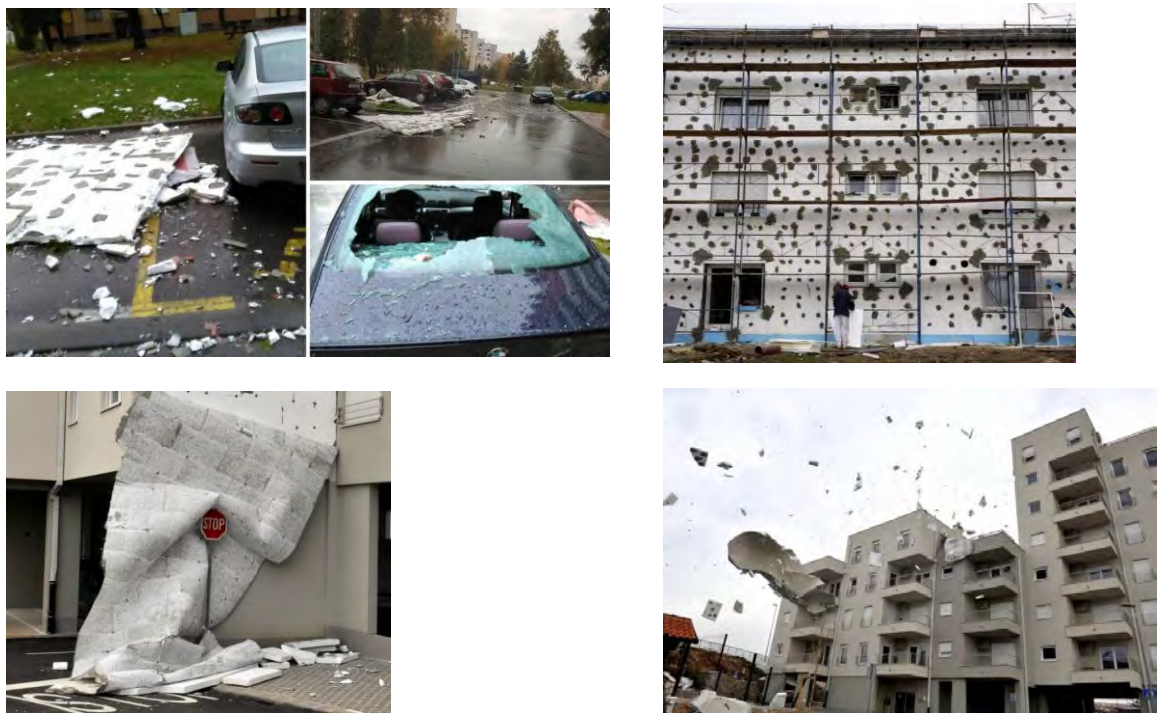
1. Competences of workers
2. Competences for DER projects
3. BIM competences for improving energy efficiency

Results from three EU funded projects will be used to assess situation in Croatian to make the roadmap for improving competences for delivering NZEBs.

### **4. Competence of workers**

The lack of qualified workers is a huge problem in Croatia due to the migration of workers to the Western European countries as well as the increasing demand for workers as a number of energy retrofitting projects grows. Moreover, professional high schools for education of workers in energy efficiency and construction are recording a decreasing number of students year after year. Thirty thousand workers are needed in the construction industry in Croatia to satisfy the current contracts (Bogdan, 2018). Analysis from 2016 (BUILD UP Skills Croatia - CROSKILLS, 2013) assessed that about 37 000 workers are needed in the AEC industry in a field of energy efficiency and Renewable Energy Sources (RES) in order to achieve the 20-20-20 targets, under the assumption that 3 % of a building's heated usable floor area would be

renovated every year up to 2050. In a line with the EED (European Parliament and Council of Europe, 2012), the Croatian government developed its 2<sup>nd</sup> National Energy Efficiency Action Plan (NEEAP) (Republic of Croatia, Ministry of Economy, 2014) by which the government highlighted the need for policy action to make buildings more energy efficient in order to meet the national energy efficiency targets. Due to the lack of construction workers, the Croatian government has defined a permissible quota of 10 070 workers who can work in Croatia (Bogdan, 2018). As salaries in the AEC industry in the Western European countries are higher than those in Croatia, there is a problem to attract enough qualified foreign workers. Even if there is enough number of workers (foreign and domestic), they must be educated for constructing NZEBs because the Vocational Education and Training (VET) programmes in Croatia related to NZEBs and DER are obsolete because they have not changed since 1996. Teaching materials used in VET programs for the AEC sector contain very little topics related to energy efficiency and DER. The educational system in Croatia is not producing workers and experts who could enter the construction market with enough knowledge and competences concerning BIM and NZEBs. As a consequence, a high number of low-quality projects are delivered (Figure 44) because even if the design is satisfying NZEB standards, buildings are not constructed according to required designed performances.



**Figure 44. Examples of low-quality construction work and its consequences.**

From the July 2017, the Ministry of Construction and Physical Planning enforced the “Regulation on education and certification system of construction workers working on the installation of building components which affects the energy efficiency of buildings” (Republic of Croatia, Ministry of Construction and Physical Planning, 2017), in order to increase the number of qualified workers for energy refurbishment of old buildings and construction of new

NZEBs. There are regulations for installers of RES systems too, and several training centres providing education are also established.

## 5. Fit-to-NZEB - competences for DER projects

Fit-to-NZEB is a Horizon 2020 project which has a goal to increase skills and competences of the professionals in the field of DER in the target countries (Czech Republic, Romania, Bulgaria, Italy, Croatia, Ireland and Greece). The goal should be achieved through the unique educational programs developed by the consortium which will contribute to both the quality and scale of the DER. The consortium developed an innovative European Qualifications Framework (EQF) level 3-7 training schemes for building retrofitting up to an NZEB level. Those training programs have been organised in the countries across Europe with a conventional structure, learning outcomes and defined competences. The program was delivered by the Universities, professional high schools, Vocational Training Centres (VTC), and through “on-the-job” training and validation programs (*Objectives & results - Fit-to-nzeb*). The partner countries performed an analysis of the existing training and educational programs for DER in order to develop the compendium of competences with the identification of gaps and deficiencies. The analysis showed that there is a lack of DER and NZEB topics in the professional, high, and higher education as well as in vocational training programs. In the EQF 3-5 systems (secondary and high education) principles of DER are not included in the official training programs at all. In the EQF 6-7 (higher education) there are fragments of DER topics represented by the certain topics without a systematical approach and the connection between them. Above mentioned problems are the main reasons why Vocational education solved the lack of qualification concerning DER. Vocational training is divided into two parts – training concerning AEC workers (EQF 4-5) and training for supervising professionals (EQF 6-7). However, this training is not harmonised and does not provide a formal DER qualification in the national qualification frameworks of the partner countries. As the analysis had shown the necessity of developing a unique DER program for each EQF level, the Fit-to-NZEB project delivered all the necessary requisites (Table 33) for the introduction of educational content regarding DER and NZEB at all the educational and training levels in South-eastern Europe (Milovanović *et al.*, 2019).

**Table 33. Developed topics for DER with short descriptions (Milovanović *et al.*, 2019).**

Topic and subtopic	
1.	Basics of building physics
1.1.	Passive house principles
	Basics of building physics needed to understand the interrelations of the major principles in DER. Introduction to the passive house principles and how they work together
2.	Optimal solar gains
	Situation and sizes of openings/shading and natural ventilation
3.	Building envelope
3.1.	Thermal insulation
3.2.	Minimizing thermal bridges

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### 3.3. Highly efficient windows

Building envelope exterior and interior insulation. Thermal bridges through structural building elements, windows and doors, through cracks and gaps in building envelope. Use of highly efficient window frames/insulating doors/positioning of windows and doors.

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## 4. NZEB Neighbourhoods

### 4.1. Energy cooperatives

### 4.2. Distributed energy production systems and energy

Understanding the nZEB Neighbourhood. Energy cooperatives as isolated business or connected to a local smart grid or to the national grid. Distributed energy sources. Microgrid solutions. District level distribution grids. Impacts and benefits of the grid integration of the distributed energy production. Energy Management Systems (EMS). Assessment of the extended built boundary and energy balance of the bounded area.

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## 5. Airtightness, vapour and moisture movement, wind tightness

Infiltration and/or exfiltration heat losses, quality assurance and blower door test. Vapour movement through the construction fabric, relevant properties of different materials.

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## 6. Building services

### 6.1. MVHR

### 6.2. Heating and Cooling

### 6.3. DHW

### 6.4. Automation – Regulation

### 6.5. Lighting

Emerging technologies in building services for high performance residential projects.

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## 7. Conservation of historic building fabric

Different levels of conservation, concept of authenticity, technical concerns in DER of buildings of historic value – suitable materials and techniques.

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## 8. RES in building renovation

### 8.1. Long and short term energy storage

Installation of RES systems in DER without interfering with nZEB principles and requirements. Possibilities of long and short-term storage of energy in the building.

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## 9. Cost effectiveness

Provision of solutions with proven cost effectiveness within the whole life cycle of the building, economic efficiency of a package of measures.

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## 10. Planning and design instruments

Nationally recognized software tools/other available software planning tools. BIM tools.

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## 11. Comfort, health and safety requirements in buildings, incl. indoor air quality

### 11.1. Summer comfort/ passive cooling

### 11.2. Fire protection

Comfort, health and safety requirements in buildings, indoor air quality, condensation, humidity and mould appearance, CO<sub>2</sub> levels, draught elimination, productivity and health impact, light, acoustic. Fire protection issues. Summer comfort.

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## 12. Step-by-step retrofit plans

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Economic assessment, energy audit, design and implementation issues. Step-by-step strategies as well as suitable component and alternative solutions.

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### 13. Energy efficiency and building renovation policies

National and EU strategic goals; financing schemes and opportunities; relevant legislation acts in nZEB construction and DER.

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### 14. Achieving measurable results

Energy audits; required parameters of the building components; energy performance certificates (EPC). Monitoring and evaluation of the results of the retrofit projects. International retrofitting standards (e.g. EnerPHit).

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### 15. Engaging stakeholders

Benefits of energy efficiency to different target groups – energy and financial savings, increased comfort, sanitary and health conditions, better indoor air quality, ecological and climate change mitigation, broader economic and social benefits, energy security, etc.

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### 16. Project management

#### 16.1. Quality assurance

Introducing basic principles – Initiating; Planning; Executing; Monitoring; Controlling of project. Increase knowledge of investment efficiency, multicriteria assessment, life cycle assessment, energy efficiency legislation used for project management and evaluation.

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### 17. Ecology and sustainability

Ecology as a starting point for energy efficiency in building; climate change and CO<sub>2</sub> levels; building materials

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Developed compendium of competences is intended for the developers of new training and educational programmes on NZEB renovations. Elaborated learning outcomes can be applied to the development of a wide range of training programmes of vocational or specialised education for AEC specialists so here are the training programs developed by project Fit-to-NZEB described in details in (Milovanović *et al.*, 2019):

“EQF level 6-7: A design-focused training programmes on DER for higher education, 60 hours of training (30 theoretical hours and 30 practical hours), with all necessary requisites.

EQF level 3-5: A training programme to be included in the professional high schools in training plans and programmes for the tradesperson professions in “Construction”, consisting of 24 theoretical hours and 36 hours of practical training. Training content for professions in “Electrical engineering and energy sector” professional direction was also developed, consisting of 24 hours of theoretical and 18 hours of practical training.

EQF level 3-4: Two training programmes for acquiring qualification on the part of the profession (specialization, or similar qualification according to each national qualification framework), to be used by the VTCs, 16 hours of theoretical and 24 hours of practical training. A comprehensive scheme for validating competences acquired at the workplace, consisting of entry-level tests, with theoretical and practical training (8-12 hours) and evaluation scheme.”



The partner countries created training models which represent parts of a real building in order to show good examples of constructed building details. The models were used for practical training demonstration. Visualisation by developed models (Figure 45) during the training programs is an essential method for better learning outcomes.



Figure 45. a) example of the training models, b) execution of the university training – blower door, c) university training – minimising thermal bridges, d) on the job training in Ireland (Milovanović *et al.*, 2019).

## 6. Net-UBIEP - BIM competences for improving energy efficiency

In Croatia BIM is used by early adopters and primarily restricted to architectural design offices. BIM usage also lacks interdisciplinary collaboration within the BIM design process (by Croatian Chamber of Architects) with very little knowledge of collaboration formats (e.g. BCF, .ifc, .gbXML) and standards (e.g. buildingSMART standards, BSI BIM standards) for the information transfer between the stakeholders. There is also no sign of BIM in Croatian construction legislation. There are some current initiatives towards BIM standardisation through Croatian Standards Institute, but currently, there is no national standard which defines requirements for BIM professional profiles. BIM professional profiles, with their responsibilities and BIM competences, are scarcely defined in “General guidelines for BIM approach in civil engineering” (Jurčević *et al.*, 2017) by Croatian Chamber of Civil Engineers, but they are quite general and do not describe BIM professional profiles in details.

Net-UBIEP is also a Horizon 2020 project which aims to increase the energy performance of buildings by BIM usage through all the building lifecycles. In each phase of the building lifecycle, it is crucial to take into account all the energy aspects in order to decrease the environmental impact of a building during its lifecycle (*NET-UBIEP project | Build Up*). BIM will allow simulation of the energy performance of buildings and check many variant solutions by using different materials and components in every iteration in all phases of lifecycle. The project proposes BIM Qualification Models to spread a better understanding of energy-related issues so that both existing and new buildings will have better energy performance. Public Administrations, Professionals (Engineers/Architects), Technicians (Installers/Maintainers) and Tenants were involved in the Net-UBIEP activities (*Project | Net-UBIEP*). Each stakeholder will have to understand which information they need to manage so other stakeholders could use it during the lifecycle of a building. The integrated BIM Qualification Models have been validated through the project thanks to the delivering of the different training activities (Seminars/Classrooms, Courses/E-Learning, Courses) addressed to at least six BIM Professional Profiles: BIM Manager, BIM Evaluator, BIM Coordinator, BIM Expert, BIM facility manager, BIM user. The training schemes were developed, and they are under the

process of validation through a survey carried out by the project partners in the moment of writing this paper. After the process of validation is done by all the project partners, all partners will propose ways of standardisation of the training schemes to find a broader acceptance at European and international level through the regulatory organisations. List of the competences related to energy performance needed for each BIM profile was defined. Competences on energy performance for each BIM profile are mapped to the defined target group.

The project partners have developed the definition of the digital competences needed to increase the energy performance of a building for each target group. By the research (Net-UBIEP) each project partner assessed the needed level of these competences grouped by the building lifecycle phases for each target group (Strategic Design, Preparation and Briefing, Concept Design, Developed Design, Technical Design, Construction, Handover and Closeout, In use). After the assessing of needed competences, three-dimensional matrix of competences was developed (Figure 46) and used for creating training and information materials.

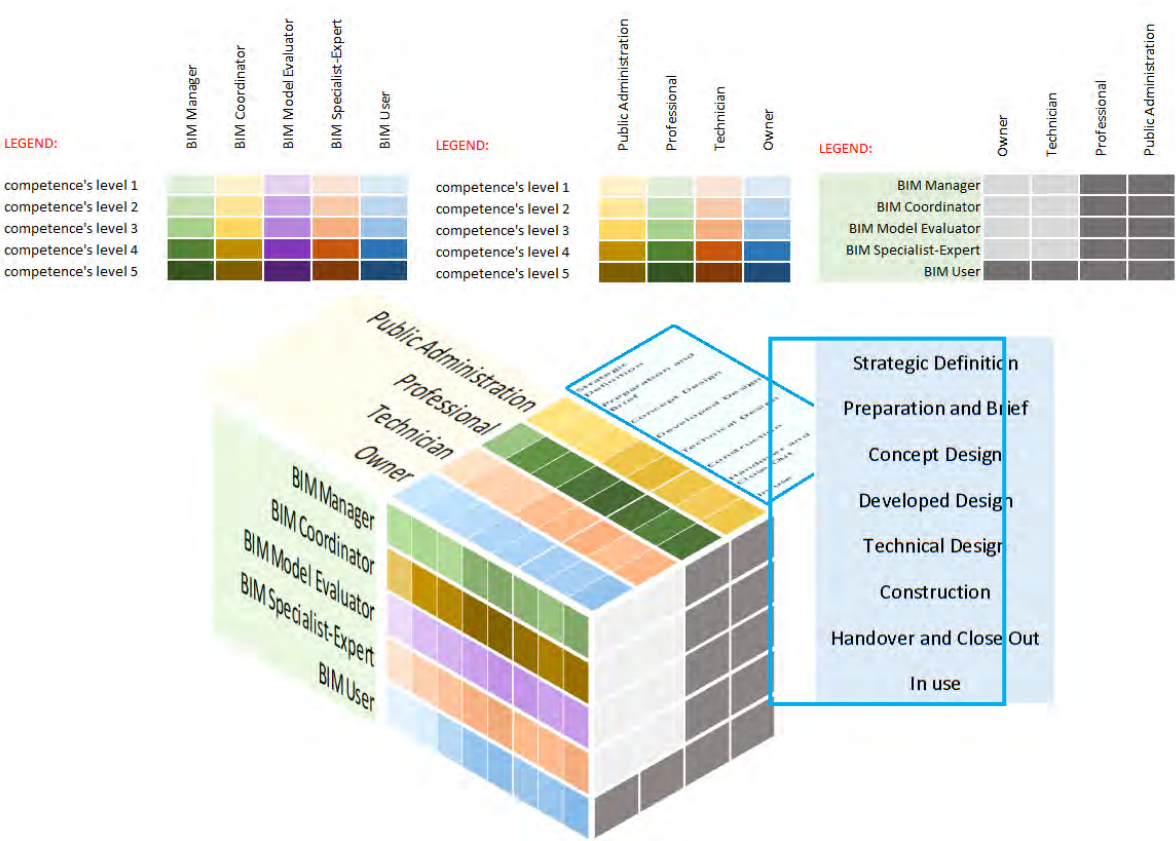


Figure 46. The three-dimensional matrix of competences for BIM-AEC stakeholders.

As a final goal of the project Net-UBIEP, training and information materials were developed: Information Material for Public Administration, Information Material for Owners, Training Material for Professionals, and Training Material for Technicians. Concerning the developed materials, every project partner has organised pilot trainings and seminars which were validated by the participants.

Faculty of Civil Engineering (University of Zagreb) as the project partner institution provided a survey amongst Croatian AEC professionals in order to map BIM competences and to validate the training materials.

Pre-training questionnaires were filled before every training so the profile and the competences of a group could be seen. After the questionnaire was carried out, training based on the *training and information materials* for each target started, after which a post-training questionnaire was performed. For the sake of brevity, this paper does not show all the results. Only results that show how well the participants accept BIM are presented. The rest of the survey results can be seen in the project reports.

In the pre-training survey up till now participated 93 participants mostly coming from engineering companies involved in residential projects, value under 1.000.000 EUR. (**Error! Reference source not found., Error! Reference source not found.**, Figure 47). In this sample only 38% companies use BIM Figure 48 but most of them only one year (Figure 49) and on small projects Figure 50. This we found unusual because BIM shows its full potential for projects with a higher value, because of the possibility of storing and organising a high amount of different information. It is interesting that 62 % of projects on which BIM was used are related to energy efficiency. Another interesting information is that none of the participants who use BIM is working on NZEB project for new buildings (Figure 51).

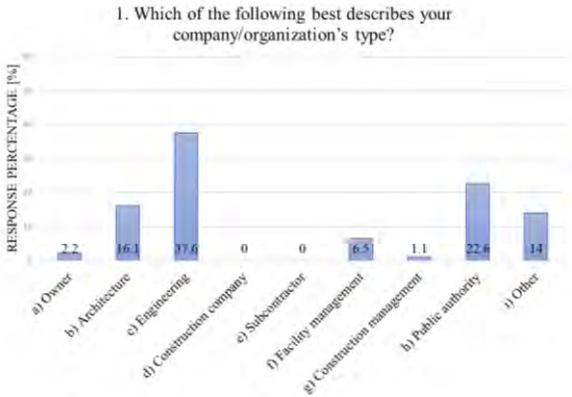


Figure 6. The profile of AEC professionals who attended the survey.



Figure 7. Types of construction projects on which participants work on.

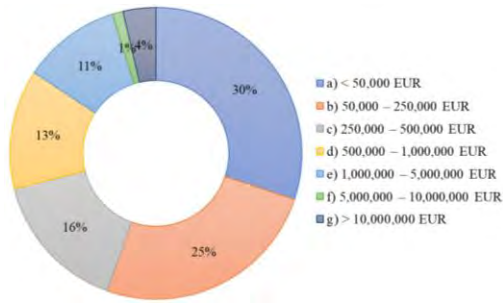


Figure 47. Value range of the projects on which participants work on.

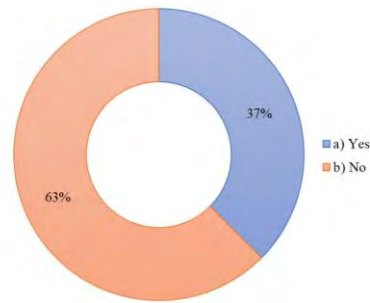


Figure 48. Percentage of training participants who use or intend to use BIM in their companies.

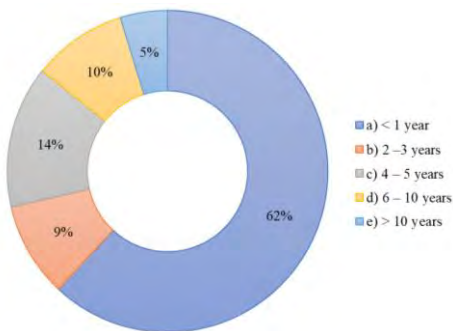


Figure 49. Experience of participants in BIM whose companies implemented BIM.

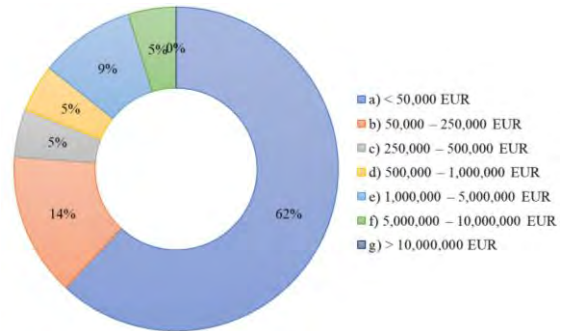


Figure 50. Project value on which participants work, for those who use BIM.

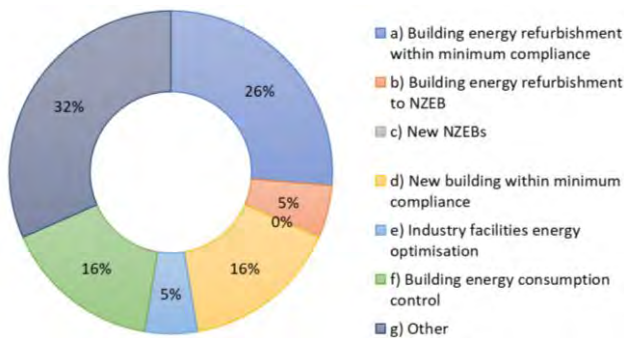


Figure 51. Relation of the BIM projects to energy efficiency, for those who use BIM.

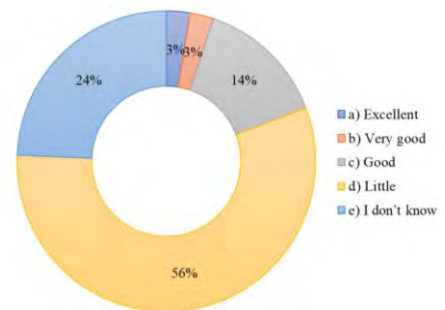


Figure 52. Competences in BIM of the participants.

In pre-training questionnaire self-assessment of competences for BIM resulted with only 6 % of the participants with BIM competences rated as excellent or very good (Figure 52), 70 % of them with good or poor, and 24 % could not rate their competences.

## 7. Conclusion

This paper described problems in the AEC industry in Croatia concerning the DER and delivering NZEBs. The analysis of current formal and informal educational programs in the AEC industry revealed that topics related to the DER and NZEBs are not adequately covered, or not covered at all, resulting with a lack of qualified workers and professionals. Another major problem detected in the conventional project delivering is an absence of integrated or interdisciplinary approach between all the stakeholders. Introducing BIM approach and defining new BIM competences can overcome this problem.

Through the preliminary survey research, it can be concluded that, in Croatia, BIM is not efficiently used in projects concerning NZEBs as only 37 % of participants use BIM and 62 % of those who use it have less than one-year experience in BIM. Problems will be experienced in a more meaningful manner after 31<sup>st</sup> of December 2020 as a massive deployment of NZEBs will start, both because of lacking qualified workers and increasing demand for delivering NZEBs. It is clear that BIM must be used in delivering NZEBs as better *information management* could be provided in order to store approved information through NZEB's lifecycle so mistakes concerning *information loss* could be minimised. Another reason for BIM usage while designing and delivering NZEB is the possibility of testing more variant solutions in order to find a cost-optimum.

Fit-to-NZEB training programs will increase competences in constructing NZEBs, and Net-UBIEP in designing, constructing, maintaining, and demolishing buildings by using BIM in all building's lifecycles. Concerning Croatian AEC stakeholders who participated training courses it can be seen that the most of them were very satisfied with the course (86 % have rated the course as "Excellent" or "Very good") but 61 % of them think that the training materials lack practical examples of BIM usage.

Another important European project has started recently. It is an Erasmus+ project BIMzeED which is closely related to the Net-UBIEP project. The BIMzeED project will try to overcome mismatched skills and improve competences of Trainers, SMEs, site managers, craftworkers and other experienced operatives in the current European AEC industry concerning BIM and NZEBs. Improving mismatched skills and competences will lead to better employability (especially for young people) and decrease of greenhouse gas emissions.

All three projects, Fit-to-NZEB, Net-UBIEP and BIMzeED, are dealing with the different aspects of energy efficiency. Improving competences of all the stakeholders in the AEC industry by combining activities of all three projects will undoubtedly increase the quality of NZEBs.

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# CROQF FRAMEWORK project 2015 – 2019

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## Abstract:

The FRAMEWORK (OKVIR) project was carried out in 2015 and 2016 with the aim to adapt undergraduate and graduate civil engineering studies in Croatia to modern labor market needs and educational qualification standards in Europe. The project was co-financed by the European Social Fund (ESF) through the Human Resources Development Operational Program 2007-2013. Planned permanent results of the project were the establishment of qualification standards for undergraduate and graduate university studies of civil engineering based on learning outcomes and improvement of teaching competences through teachers' education. Authors of the article researched and analyzed current status of Framework project's results in 2019, three years after its completion, based on achievements stated in the proposal and final report of the project. A discussion of the interaction of the Croatian Qualification Framework development (CROQF) at national level with Framework project's specific elements and phases was conducted and resulting shortcomings were presented and explained. Finally, guidelines and recommendations on how to fully accomplish goals set within the Framework project were outlined for the future period, accentuating the importance of introducing different stakeholders in the process by networking higher education and labor market in the field of construction.

*Keywords: qualification standards; learning outcomes; higher education; labor market*

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## 1. Introduction

The Government of the Republic of Croatia adopted the National Reform Program 2019, which defines priorities of economic policy as well as measures needed to achieve the goals of the Europe 2020 strategy. The main objectives of the program are strengthening the competitiveness of the economy, attaining the sustainability of public finances and linking education with the labor market [1].

The Reform Program states, among other things, the necessity of improving the quality and relevance of higher education in Croatia based on the introduction of professional practice as a mandatory course within study programs. This reform measure stems from the disharmony between the needs of the economy and academic programs as well as low representation of practical skills in curricula that provide students with greater employability options [1].

The Croatian Qualifications Framework (CROQF) is a reform instrument that regulates the entire system of qualifications at all educational levels in the Republic of Croatia through qualification standards based on learning outcomes and adapted to the needs of individuals, the labor market and the whole society [2]. In order to make full use of the CROQF in higher



education, European Social Fund financing enabled the development of qualification standards, occupational standards and/or development of new lifelong learning programs.

The *Development and application of the Croatian Qualifications Framework in the field of higher education of civil engineers* (acronym FRAMEWORK) project was carried out in 2015 and 2016 with the aim to adapt civil engineering studies in Croatia to modern labor market needs and educational qualification standards in Europe. Its goals, activities and planned outputs were outlined in the project proposal while the project's final report stated FRAMEWORK's actual achievements and their expected effects.

Since then, in the period between 2016 and 2019, the qualification framework in Croatia, together with its supporting elements like sectoral councils and Register, did not develop as foreseen in various national documents and acts. Therefore, the alliance of civil engineering faculties, that connected in order to carry out the FRAMEWORK project, was faced with several impediments when trying to fully realize and further its outcomes.

This article deals with subsequent evaluation of FRAMEWORK's results in 2019, assessing their presence, durability and quality while simultaneously assessing the success of the Croatian Qualifications Framework in general. Based on that research, the authors outlined proposals for a faster and more efficient implementation of all aspects of the FRAMEWORK project, accentuating the importance of introducing different stakeholders in the process by networking higher education and labor market in the field of construction.

## **2. Theoretical and practical basis for Croatian Qualification Framework (CROQF)**

### *2.1 Croatian Qualification Framework (CROQF) - description*

The Croatian Qualifications Framework (CROQF) is a tool for the design of a qualification system in the Republic of Croatia that provides clarity, acquisition, quality and permeability of qualifications as well as the possibility of linking qualifications in the Republic of Croatia with European Qualification Framework and indirectly with levels of qualifications frameworks in other countries. The qualification standards legislative and institutional framework has been developed and established to be used as common criteria for the quality of education, study programs and occupational standards, and as a tool for adapting to the needs of the labor market.

Legislative basis for introducing qualification standards in Croatia consists of three major acts:

- *Law on Quality Assurance in Science and Higher Education (Official Gazette 45/09)*
- *Croatian Qualifications Framework Act (Official Gazette 22/13, 41/16-Resolution USRH, 64/18)*
- *Rule book on the Registration of the Croatian Qualifications Framework (Official Gazette 62/14).*

Sectoral councils, expert and advisory bodies have been set up, their key task being evaluating proposals of standards of occupation and qualification standards. The legislative and institutional framework for the implementation of the evaluation and entry of the standards of

occupation and qualification standards into the Register of the CROQF has been fully developed.

## *2.2 Current developments of the Croatian Qualification Framework (CROQF)*

The CROQF Register has been established for the purposes of data collection of learning outcomes, occupational standards, qualification standards, learning outcomes' evaluation programs, qualification programs and other data of interest that could be used to connect and align acquired information [3].

As of April 30 2019, there were 146 entries into the CROQF Register (available at <https://hko.srce.hr/registar/>, accessed April 25 2019); 11 occupational standards, 135 sets of competences and zero qualification standard and sets of learning outcomes. Evaluation procedures are ongoing for another 77 requirements for registering occupational standards and 3 requirements for registering of qualification standards.

Members of the Sectoral Council in the field of construction were appointed in January 2017. In September 2017, Sectoral Council VIII, Construction and Geodesy, held its first, constitutive session. (available at <http://www.kvalifikacije.hr/hr/odrzane>, accessed April 25 2019).

## *2.3 Project cycles*

The Croatian Qualifications Framework has strong support in European policies, therefore European funds have been provided for the implementation of projects that contribute to the development of educational programs with the use of tools of the Croatian Qualifications Framework. So far, three project cycles have been financed in connection to the development and implementation of the Croatian Qualifications Framework (Table 1).

In the first cycle, the projects were financed under IPA Component IV, Operational Program for Human Resources Development, Priority Axis 3: Strengthening Human Capital and Employability, Measure 3.1 - Further Development of the Croatian Qualifications Framework. Approved projects contributed to the implementation of the Croatian Qualifications Framework through the evolution and modernization of systems and qualifications on different levels of education, the development of curricula / programs based on learning outcomes, including developing capacities for student-oriented learning. This project cycle was primarily aimed at elementary and secondary education, vocational education and training. Under the program, 16 projects were financed in the amount of HRK 38 million (around 5 million EUR), in the period from 2013 to 2015. Reform of the qualification system at the national level was strengthened by the adoption of the Croatian Qualifications Framework Act in March 2013.

Table 1. Overview of three funding cycles of CROQF projects

Title of the Project Call	Number of financed projects	Amount of financed projects (HRK)
Further Development and Implementation of the Croatian Qualifications Framework	16	38.000.000,00
Improving Quality in Higher Education through the Application of the Croatian Qualifications Framework	30	64.054.117,65
Implementation of the Croatian Qualifications Framework in Higher Education	26	99.609.966,04
In total	72	201.664.083,69

The second project cycle was funded under the 2007-2013 Human Resources Operational Program, European Social Fund, Priority 3. Improving Human Capital in Education, Research and Development Measure 3.1. Improving the educated system. Approved projects were funded with the aim of improving the quality of higher education through the development and implementation of the Croatian Qualifications Framework, qualification standards, new and improved study programs, teaching competences, student centered approach in teaching and learning. Thirty projects were financed in the amount of HRK 64 million during 2015 and 2016 (Table 2).

Table 2. Overview of second-cycle CROQF projects structured according to HEI and science areas

	University Zagreb	University Rijeka	University Split	University Osijek	University Zadar	University North	Polytechnic Požega	Polytechnic Zagreb	ZSEM	Libertas	Polytechnic Virovitica	Polytechnic Rijeka
Technical sciences	3	1	2	1				1				
Social sciences	1	2	1	1	1				1	1	1	
Biomedicine and health	1		1									
Biotechnical sciences	1			1								
Art												
Natural sciences			1									
Humanities												
Interdisciplinary science areas	3	1	1			1	1					1

Source of data: [http://www.kvalifikacije.hr/sites/default/files/news/2017-04/Odluka\\_5.pdf](http://www.kvalifikacije.hr/sites/default/files/news/2017-04/Odluka_5.pdf)

In the third cycle, currently ongoing, projects are funded under the Operational Program for Human Resources Effective 2014-2020 of the European Social Fund, Priority Axis 3. Education and Lifelong Learning, Investment Priority 10.II. Improving the Quality and Effectiveness of Tertiary and Equivalent Education and enabling access to increase

participation and acquisition of such education, especially for disadvantaged groups, Specific Goal 10.II.1. Improving the quality, relevance and effectiveness of higher education programs. Approved projects are funded with the aim of improving the quality of higher education through the development of study programs, quality assurance tools, competences of higher education institutions' staff and students and relevance of teaching activities in higher education. Twenty-six projects were carried out in the amount of HRK 99 million (Table 3).

Figure 1 illustrates the allocation of funding of the second and third CROQF projects' cycles according to the science areas. Funding trends shifted from an even distribution between social, technical and interdisciplinary areas of science in the second cycle towards more technically oriented projects within the third cycle, based on national emphasis on the STEM domain.

Table 3. Overview of third-cycle CROQF projects structured according to HEI and science areas

	University Zagreb	University Rijeka	University Split	University Osijek	University Zadar	University Pula	Algebra	Polytechnic Velika Gorica	Polytechnic Bjelovar
Technical sciences	4	1	1	1			1	1	1
Social sciences	1	2	1		1				
Biomedicine and health	2		1						
Biotechnical sciences	1								
Art	2								
Natural sciences		1							
Humanities		1							
Interdisciplinary science areas	2					1			

Source of data: <https://mzo.hr/hr/odluka-o-financiranju-projekata-iz-poziva-na-dostavu-projektnih-prijedloga-provedba-hko-na-razini>

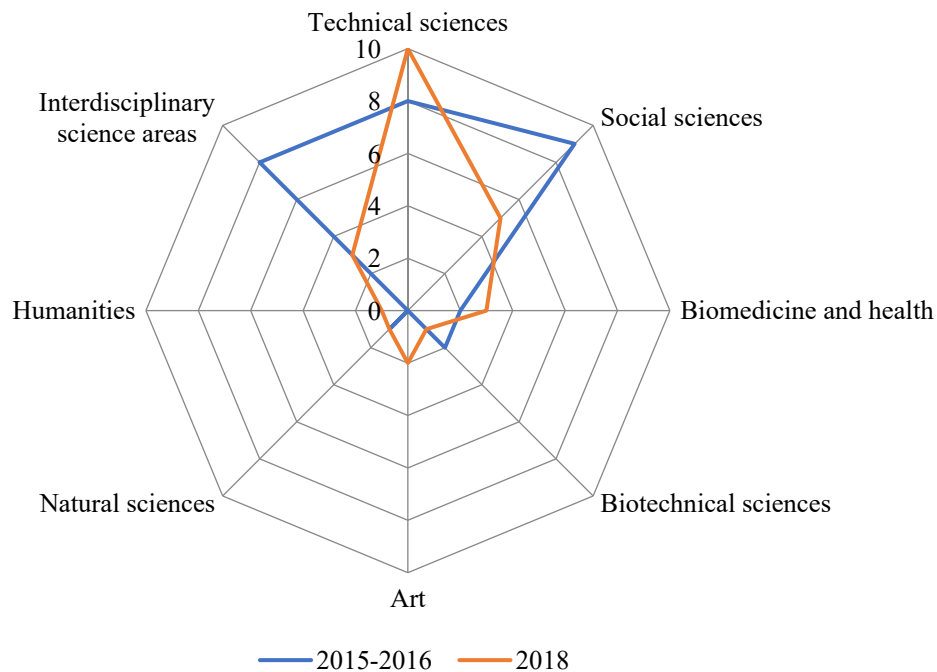


Figure 1. Graphical description of the allocation of CROQF projects of the second and third cycles according to science areas

### 3. Project FRAMEWORK

#### 3.1 Project description

Project Development and application of the Croatian Qualifications Framework in the field of higher education of civil engineers (acronym FRAMEWORK) has been carried out within the framework of the 2007-2013 Human Resources Operational Program, Priority 3: Improving Human Capital in Education, Research and Development. The project was co-financed by the European Union from the European Social Fund (ESF).

The project leader was the Faculty of Civil Engineering Osijek, performing project activities with its partners - Faculty of Civil Engineering Zagreb, Faculty of Civil Engineering Rijeka and Faculty of Civil Engineering, Architecture and Geodesy Split. The project's strength was the partnership between all four faculties of civil engineering in the Republic of Croatia, providing a comprehensive approach to qualification standards and learning outcomes of undergraduate and graduate university studies at the national level. The contracted value of the project (amount of contracted eligible costs) is HRK 2,992,281.59, of which HRK 2,600,891.16 is financed by the European Social Fund. The duration of the project was 15 months, starting June 18, 2015 [4].

#### 3.2 Project Goals

The aim of the project was aligning civil engineering studies with qualification standards in order to achieve a socially acceptable level of professional knowledge based on Croatia's strategic goals and labor market needs.

Planned permanent results of the project were the establishment of qualification standards for undergraduate and graduate university studies of civil engineering based on learning outcomes and improvement of teaching competences through teachers' education.

### 3.3 Activities - project elements

Activities within the project were structured through following work packages:

- education of members of the project team on the Croatian qualification framework, learning outcomes and education policies,
- education of teachers and external stakeholders on the reform of higher education through the instruments of the Croatian Qualifications Framework,
- professional practice packages for 120 students, designed to develop and establish a model of professional practice and evaluate the learning outcomes gained through it,
- analysis of the construction profession, labor market and education policies as a basis for developing qualification standards and learning outcomes of study programs,
- series of professional workshops for teachers with the aim of developing and upgrading their pedagogical, didactic and technical skills,
- proposal of the qualification standard for undergraduate and graduate university studies in civil engineering and improvement of existing study programs based on learning outcomes (4 undergraduate and 21 graduate study programs) and
- round table organized with the aim of creating a dialogue between all stakeholders in the construction area with possible scenarios of engineering education in the future [5].

### 3.4 Project Outputs

*Qualification standards' proposals, as a result of this project, are a permanent reference of educating civil engineers.* The application of these proposals should have been assured by the established legislative framework and principles promoted by the Croatian Qualifications Framework. The work on drafting the standards' proposal was made possible by the cooperation of higher education stakeholders - teachers, students and external experts - who gained specific knowledge about the qualification system and the learning outcomes through the project activities. Further activities in this area are aimed at registering these standards in the CROQF Register.

Learning outcomes of 25 study programs, as a result of this project, are the basis for further modernization of study programs. The acquired knowledge of teachers and external experts should enable continuous work on developing learning outcomes, criteria and evaluation procedures.

The implementation model of professional practice, as a result of this project, bases its sustainability on the cooperation between faculties and employers. The model has been established in order to function through various labor market challenges delivering mutual benefits to all stakeholders.

Increasing teachers' capacities to apply modern teaching methods as a result of this project, rely on the implementation of compulsory teacher training in strategic documents of all four

civil engineering faculties. Throughout the project, 158 teachers were trained to implement modern methods into the teaching process. In the future, such teacher training programs should originate from faculties' quality offices.

#### **4. Status of FRAMEWORK project in 2019**

Authors of the article researched and analyzed the status of Framework project's results in 2019, three years after its completion, based on achievements stated in the proposal and final report of the project. A discussion of the interaction of the Croatian Qualification Framework development (CROQF) at national level with Framework project's specific elements and phases was conducted and resulting shortcomings were presented and explained.

##### *4.1 Methodology and data collection*

Data used for the analysis of FRAMEWORK project's lasting effects was collected researching re-accreditation reports of the Croatian Agency for Science and Higher Education (ASHE). Three faculties of civil engineering in Croatia were visited and inspected in 2018 - Zagreb, Split and Osijek - and subsequent re-accreditation reports were issued and presented in 2018 and 2019. Faculty of Civil Engineering in Rijeka, the fourth FRAMEWORK project partner, has postponed the re-accreditation visit, therefore offering no comparable information for this research.

##### *4.2 Results and discussion*

Qualification standards developed within the project have not been registered and have remained at a proposal level.

Main reason for this activity lagging is the fact that the CROQF Register has only been established in 2017, as well as the Sectoral Council VIII, Construction and Geodesy. Currently, not one qualification standard in Croatia has been registered, regardless of the area. Of the 80 various entries that are under consideration, only three are qualification standard proposals, all originating from interdisciplinary areas of science. These numbers point to a long and complicated verification procedure, making the qualification standards' entry into the CROQF Register unattainable so far.

Learning outcomes of 25 study programs have been developed within the project but have not been formally adopted.

The comprehensive change of curricula at faculties of civil engineering in Croatia was from the start a far-reaching goal that was to be accomplished gradually. For it to happen, additional cooperation and communication between the faculties, corresponding ministries, their surroundings and local communities, professional bodies like the Croatian Chamber of Civil Engineers as well as representatives of the construction market should be achieved.

All institutions are in the process of modifying curricula and relevant ASHE re-accreditation reports made clear that all faculties have defined learning outcomes that are aligned with CROQF levels and qualification profiles, reaching at least satisfactory academic quality levels (in Zagreb, Split and Osijek, based on comparable data available in 2018).

However, it is necessary to implement a clear and systematic process of verifying accomplished learning outcomes versus the anticipated ones in order to assess the actual quality of these study programs.

The model of professional practice is in the process of development and implementation.

The draft of the professional practice model and the feat of sending 120 students to various companies and institutions for a one-month professional stay has served as a successful preparation for the development and implementation of professional practice as an obligatory course within the study program. A project cycle called *Development, improvement and implementation of professional practice in higher education* has been opened and a review of project proposals is currently under way (two of four faculties have applied). The project cycle is co-financed by the European Union through the European Social Fund (ESF), Human Resources Development Operational Program 2014-2020.

According to ASHE re-accreditation reports student professional practice should be formalized and implemented in the undergraduate as well as the graduate studies.

Teachers' capacities after the completion of the FRAMEWORK project were significantly increased and have been evolving since.

The project encouraged co-operation between more than 150 teachers and gave them the opportunity to re-examine and improve their own approach to the education process. Workshops with focus on pedagogical, communicational, inter-personal aspects of teaching in the STEM area are no longer isolated, project-based acts but rather activities performed on a permanent basis. Re-accreditation reports emphasized teachers' capacities and qualities as one of the faculties' strengths.

## 5. Conclusions

The FRAMEWORK project has been in existence for over five years now, taking into account its consecutive phases from the first idea through application, implementation, completion and after-life.

At the beginning of this process, the complexity of the Croatian qualification framework - including legislation, chronology, composition and harmonization of various stakeholders - was not as evident to FRAMEWORK's leaders and team members as it was after the completion of the project. The project was planned with the aim to define and record learning outcomes at bachelor and master level of civil engineering university studies, while accepting inputs from the market, civil engineering practitioners and students. However, the subsequent application of these results in form of modified study programs and qualification standards inscribed into the CROQF Register, proved to be a task more difficult than envisioned.

FRAMEWORK's positive and viable outcomes, as foreseen in the project proposal and affirmed in its final report, are visible in 2019 at all four faculties of civil engineering in Croatia.

First, teachers' competencies in areas like information and communication technology, collaborative teaching, project and problem based learning and other current pedagogical



advancements, were strengthened and enforced quantitatively and qualitatively through workshops, educational visits, lectures, meetings and discussions.

Second, the composition of working groups within the project joined stakeholders that differed both institutionally (faculties, construction sector companies, design offices, local government) and geographically, therefore providing a lasting platform for networking within all facets of the construction business.

Lastly, the project accentuated the significance of acquiring practical experience during academic studies before entering the labor market. This resulted in preparations for the implementation of on-field practice as an obligatory course in current civil engineering study programs in Croatia. Two of the faculties have applied for European financing in that area.

Still, the civil engineering qualification standard at university level has not yet been presented to the Sectoral Council VIII, Construction and Geodesy. Neither has any other application been filed to this sectoral council and of the 25 sectoral councils established in Croatia so far only two applications have been checked-in and are in consideration.

These numbers depict a system yet to be fully developed. One must reconsider the limitations and deadlines that are currently in place and modify the system to be more transparent, straightforward and efficient. Additional effort should be put into informing the institutional applicants about the registration process. Also, suggestions and corrections based on actual applicants' experiences should be incorporated into formal procedures.

In order to succeed in registering civil engineering qualification standards into the CROQF Register, mutual agreement and a will to proceed should be present within the alliance of civil engineering faculties in Croatia. Technical aspects of this process are mostly completed and faculties' management should now agree on the details and finalize the application. Without these steps, neither the FRAMEWORK project nor the Croatian Qualification Framework, on a more general level, can be successful and sustainable.

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# Integrating BIM into Construction Project Management Education at the Faculty of Civil Engineering in Belgrade

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## **Abstract:**

The development of information technology and communication means has a great influence on the way construction projects are prepared and delivered. One of the latest trends in digitalization in construction bringing improvement throughout construction industry is the application of Building Information Modeling /Models (BIM). BIM is used for optimization of projects in respect of time and money in all project phases. It has been noted that BIM was successful in fulfilling these goals in all countries which have imposed BIM implementation for certain types of projects in their legislation and application of BIM becomes a standard all over the world. In order to keep the pace with everyday demands of the construction industry, the Department for Construction Project Management at the Faculty of Civil Engineering in Belgrade has introduced BIM in lecturing on Construction Project Management. In the latest accreditation, two new courses have been introduced. “The basics of designing by applying BIM technology”, has been lectured at the final year of bachelor studies from the year 2017/2018. “BIM in Construction Project Management”, will be lectured at the master level starting from October 2019. Based on previous and on-going research the authors developed curriculums that will enable students to better understand the use of BIM in construction project management. This paper presents (1) previous experience of BIM education within the CPM module and (2) goals and first results of new courses being introduced in students education as well as teaching materials and applied theoretical and practical teaching methods performed in ICT labs with already implemented typical software for 3D modeling of construction and plans for introducing 4D and 5D functionalities.

*Keywords: BIM; construction project management; education; teaching goals; BIM in education*

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## **1. Introduction**

The construction industry is currently faced with many challenges. In particular, construction projects are often over budget, have reduced productivity and quality and are delayed. Once finished, they deliver less benefits than planned (Locatelli et al., 2017). One of the most important causes of these problems is lack of communication and cooperation between project participants.

A large problem in the construction industry is significantly lower productivity than in other branches of industry. Low productivity is in direct correlation with the key criteria for measuring the success of construction projects. The key criterion for success of any project in a wider sense represents a measure with which the success or failure of the project will be determined. The three key criteria for success of an investment project are: cost, time and

quality of executed works and together they represent “The Iron Triangle” of project management. Construction projects are often over-budget, late, and the final product is of unsatisfying quality (Morris, 2008; Cantarelli, Flyvbjerg and Buhl, 2012; Locatelli *et al.*, 2017). Many scientific studies tried to determine the most important factors which affect the key criteria for success of investment projects and new innovative solutions for solving these problems have been suggested. One of these suggestions is Building Information Modeling (BIM).

Investment projects are becoming more and more complex and hence harder to manage. Significant efforts are being made to introduce new solutions and approaches to project management so as to avoid or prevent potential problems. However, the construction sector is one pretty conservative and diverse industry and that makes introduction of new methods and approaches more difficult (Smith and Tardif, 2009). Implementation of new methods is limited because it is difficult to change the existing processes in order to introduce new ones.

In order for implementation of new approaches to project management to be possible, it is necessary to conduct proper education, training, and research.

## **2. Building Information Modeling (BIM)**

BIM represents a revolutionary concept and its application completely changes the traditional practice of investment project management. BIM represents a change with far-reaching impact and with its application significant benefits are accomplished, both for participants in the construction industry and the society as a whole since better objects are built with less material, less effort, and with smaller financial resources and their management and maintenance are made easier and better (Eastman *et al.*, 2011). BIM is defined as an approach to design and construction via modeling technology, by connecting the processes and people with the goal of producing, communicating and analysing building information models (Haron, 2013).

BIM can be used by project managers to improve cooperation between project participants, thus expediting creation of project documentation and in turn, making positive project results possible (Bryde D., Broquetas M. and Volm J.M., 2013). It is important to note that BIM is not just software. It is both, a process and software. In addition to representing application of intelligent 3D models, BIM represents significant changes in the work and project realization processes (Hardin and McCool, 2015). Visual cooperation represents one of the most important principles of BIM and project optimisation being done in the early phases preferably from the very beginning is a key concept of project management in construction (Rahman, 2011).

BIM is a tool which can bring significant savings throughout all the phases of a building’s life-cycle. In the design phase savings can be achieved through more efficient collaboration between the project participants and especially designers from various technical areas. Second important contribution of BIM in the design phase is efficient collision resolving and thus eliminating potential delays on the construction site and causing additional large expenses.

A centralized source of information incorporated in a 3D model ensures more efficient planning, analysing and calculations. Visualization ensures a clearer overview of the

construction process and allows for anticipation of potential issues thus providing significant contribution to the phase of realization of works.

During exploitation and maintenance of the building, the BIM model makes it possible for all the data acquired in visual inspections and tests to be entered into a unified, centralized database.

BIM can be used by all the project participants: the investor can use it to understand the project needs; the design team to analyse, design, and develop the project, the contractor to manage the construction, and the facility manager during the exploitation phase (Grilo and Jardim-Goncalves, 2010).

### **3. BIM application and education throughout the world**

BIM implementation in investment projects all over the world is rising. Even though the technology supporting BIM exists for over a decade, BIM implementation in the construction industry is significantly slower than in other industries. Use of BIM is growing rapidly, stimulated by large public and private investors who want the advantages and benefits from faster and more certain project realization and more adequate quality and costs to become the norm.

The decision made by the European Parliament in January 2014 to modernize regulations for European public procurement and prescribe the use of ICT tools such as BIM is very important. This directive instructed all 28 member nations to support, define, or order the use of BIM in realization of investment projects financed by the EU public funds by 2016 (Autodesk, 2014).

The level and scope of BIM implementation differ from country to country. There are countries in which this concept was introduced years ago but there are also those in which it is relatively recent. The level of awareness, knowledge and interest in BIM varies from country to country, discipline to discipline, investor to investor (Gu and London, 2010). Another fact is that not all the firms are implementing BIM at the same level of maturity, especially in those countries in the very initial stage of this methodology adoption (Urbina Velasco, 2013).

Research that has followed BIM implementation for the past few years shows that education and training in the use of BIM tools are a significant factor. That lack of trained personnel presents an obstacle and hinders implementation of BIM in the construction industry. BIM education, training and research are essential not only for realization of implementation but also for the development and growth of the industry (Smith, 2014). Students education represents an important step in overcoming these obstacles.

#### *3.1 World trends in BIM education*

Several decades had to pass from the beginning of development of BIM to formation of the first expert and academic courses in this field. This shows that education in the field of BIM and development of BIM curriculums are still under-way (Chegu Badrinath, Chang and Hsieh, 2016). Every day there are more and more published papers on educational approaches in this field. A lot of educational institutions in most developed and developing countries have or are

developing BIM courses in some form. However, the quality of these courses varies significantly. The reason for that is the fact that the standardized structure of courses has not yet been established.

Almost all the educational institutions in the world which have incorporated BIM courses in their curriculums, first had various programmes of expert training. These trainings were usually organized by chambers of engineers or software distributors and they mostly included the use of BIM software. In Serbia, too, there have been various commercial courses in the use of the BIM software for the last 10 years or so. This concept of training has been applied in most of the academic courses in the world. There is only a small number of universities in countries such as Australia, Great Britain, USA, and Scandinavian countries which educate their students about open BIM standards, BIM management and collaborative BIM environment (Natspec, 2018; Petronijević et al., 2018).

The first BIM association in Serbia was established last year (BIM Serbia, <http://bim-serbia.com/>) whose goal is to foster implementation of BIM in the construction industry in Serbia and raise individual, organisational and general awareness of importance and benefits of BIM application.

#### **4. BIM education at the Faculty of Civil Engineering in Belgrade**

In order to keep the pace with everyday demands of the industry, the Department for Construction Project Management at the Faculty of Civil Engineering in Belgrade has introduced BIM in education at the Faculty of Civil Engineering in Belgrade within the field for Construction Project Management. In the 2013 accreditation, two new courses have been introduced. *The basics of designing by applying BIM technology*, has been lectured at the final year of bachelor studies from the school year 2017/2018 and is mandatory for all civil engineering students on the Construction Project Management (CPM) module. The second course called *BIM in Construction Project Management* is prepared to be lectured at the master level. Based on previous and on-going research the authors developed curriculums that will enable better understanding of the use of BIM in construction project management.

The paper shows previous experiences, goals and results of BIM education through the CPM module, as well as the way in which the curriculums for the two new courses were developed.

##### *4.1 Previous experiences in BIM education*

Before the new courses were introduced, the Department for Construction Project Management at the Faculty of Civil Engineering in Belgrade educated students on BIM within the course called Project Management. The students were organized in teams and they actively participated in creation of term papers in which they researched principles, manners and benefits of application of BIM on construction projects. Through the term papers, the students got familiar with the software packages mostly used in Serbia, *Autodesk Revit and Navisworks*. Some of the students' term papers have been: Application of Softwares Autodesk Civil 3D and Navisworks, Application of Softwares Autodesk Revit and Navisworks: Connecting Building Design with Cost and Schedule Control, Application of 3D Laser Scanning for Creating of BIM

Model for Construction Quality Control. In Figure 1 an example of connection of building's BIM model created Level 2 in Autodesk Revit with the schedule plan created in MS Project by using Autodesk Navisworks is shown. This Figure is an extract from students' term paper.

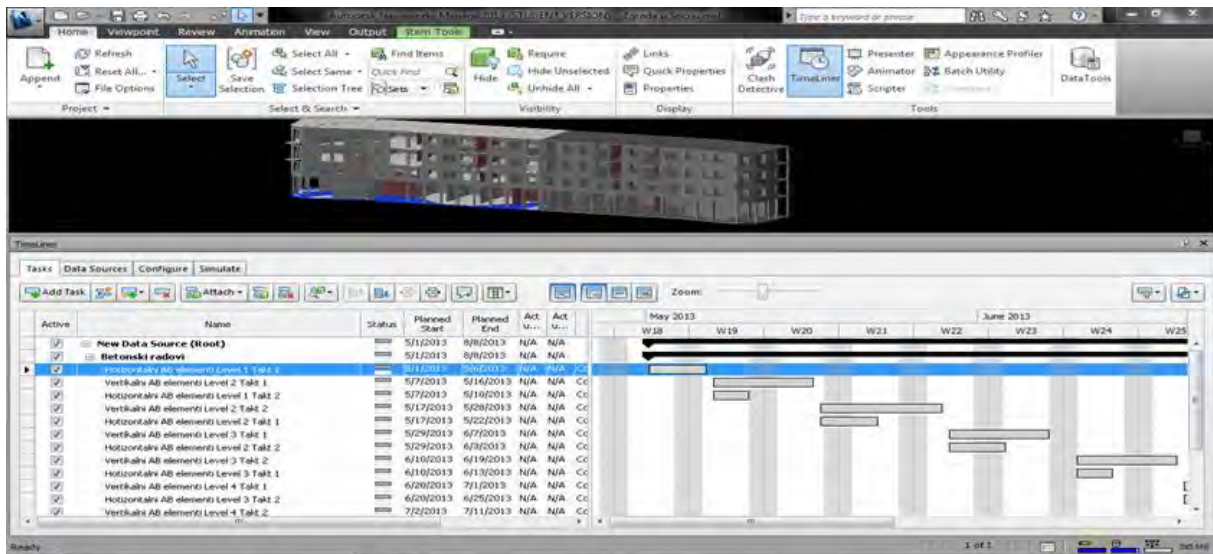


Figure 1. Connection of BIM model with schedule plan (An extract from students' term paper)

In addition to the term papers, writing bachelor and master theses also significantly contributed to the students' education in the field. When choosing their thesis, the students showed great interest in the application of information technologies in construction industry and especially integration into BIM concept. A large number of thesis included creation of a model of a building and connecting the model with the schedule plan formed within the project of organization and technology of building. Some of the extractions from students' thesis are shown in Figure 2 and Figure 3.

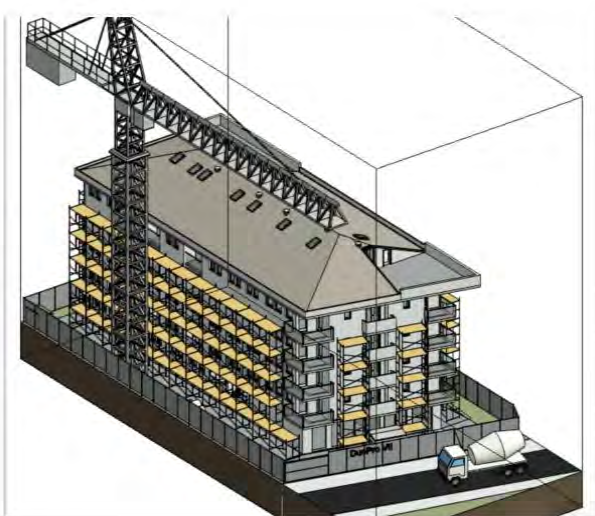


Figure 2. BIM model created with Autodesk Revit

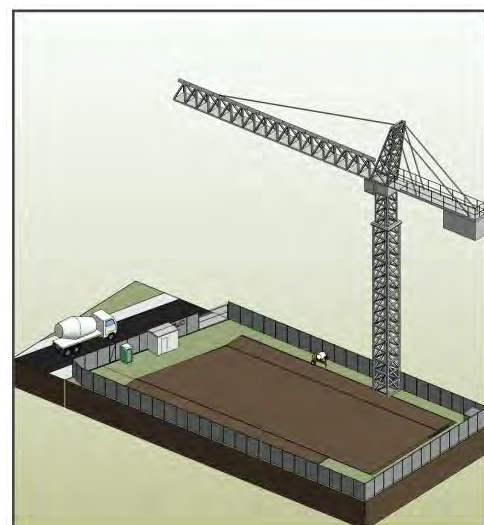


Figure 3. Site organization made in Autodesk

(Extracts from students' master thesis)

Under the mentorship of the authors of this paper, during research for their master thesis, students gained the necessary competences for application of BIM on construction projects. Familiar with the functional principles of the modeling process for construction of buildings the students obtained the necessary knowledge and skills to use as a good base for their further work and through this increased their employment possibilities.

#### *4.2 Development of BIM curriculums*

Previous experiences in BIM education through existing general project management course served as the basis for forming new courses, ones in which BIM concept will be the primary focus. Taking into account the fact that BIM is becoming the standard in the world, it is necessary to develop awareness of implementing it in Serbia so that construction companies from Serbia can become competitive in the domestic and international market. The first step towards realization of this goal is education and training of the necessary personnel. Based on the examples of good practice of BIM implementation, the competences necessary for BIM implementation on an individual level, on the organizational level, and on the country level were analysed. Overview and comparative analysis of BIM software for project management available in Serbia were also done.

There is a need for a framework for BIM implementation which is comprehensive enough to include all the relevant BIM domains and implementation challenges and all the key strategic questions which need to be taken into account when planning BIM implementation on an investment project. Most of the expert papers are based on BIM implementation on a project from the top-down perspective which follows the frameworks based on implementation on a very high technical and organisational level. The suggested framework shown in Figure 4 would be comprehensive enough to even cover projects in countries in which BIM application is not very developed, such as Serbia. It can also be applied to different types of projects, different project participants as drivers of BIM implementation on a project, different levels of maturity of BIM application, and projects in which different contractual methods of project realization are being applied (Smiljanić M., 2016).

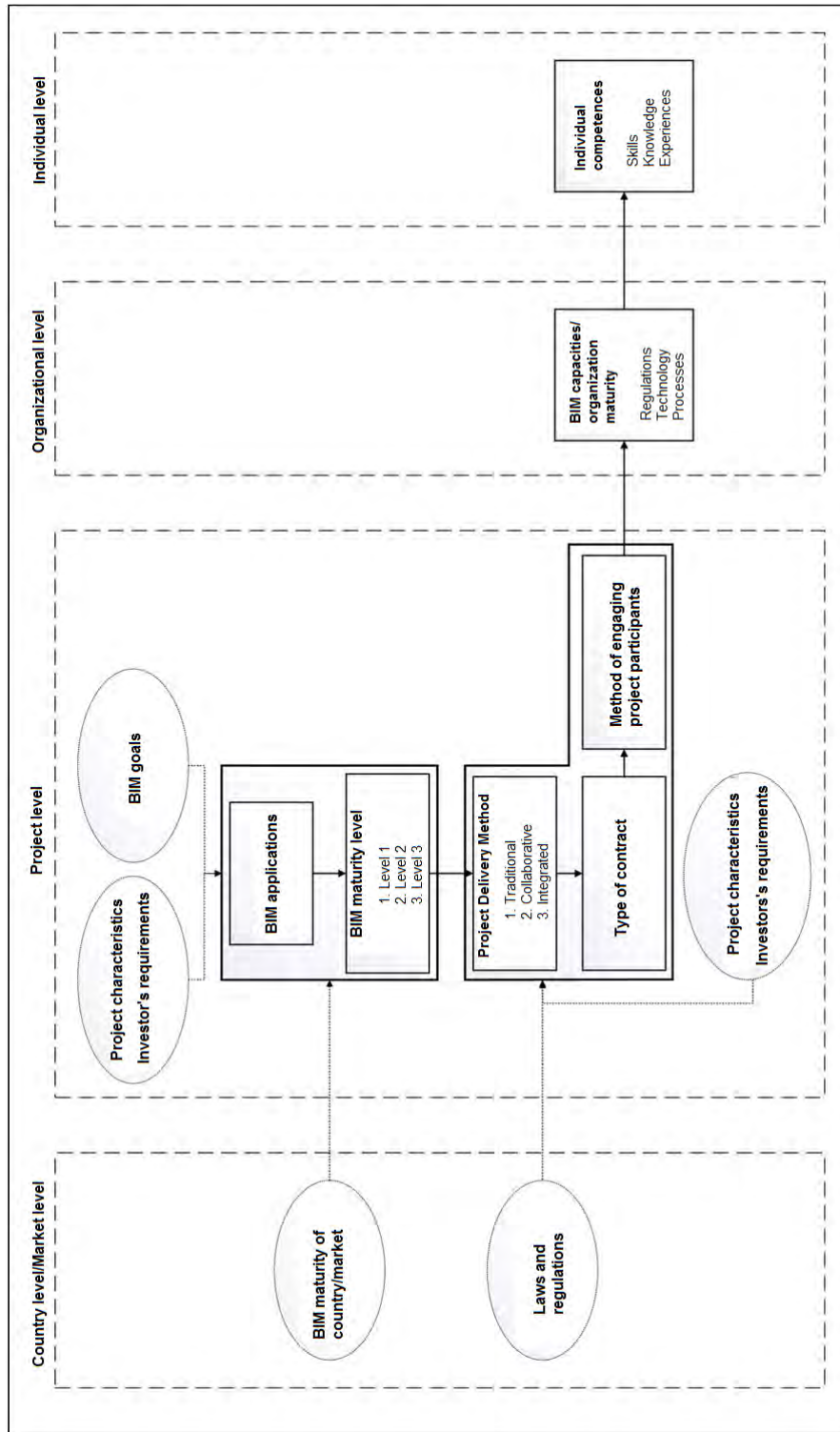


Figure 4. Framework for strategic BIM implementation on a project (Smiljanić M., 2016)



One of the most important factors which affect the success of BIM implementation on investment projects is the level of BIM maturity of the country in which the project is being realized. The highest level of BIM maturity that can be implemented on a project is directly conditioned by the factors which affect the level of BIM maturity of a country. BIM maturity of a country/market represents the level of adopting BIM by the country/market and the level of development of BIM regulations (Succar and Kassem, 2015). According to the paper (Succar and Kassem, 2015) eight complementary components for measuring and achieving BIM maturity of countries and other macro organisational systems are identified. They are: objectives, stages, and milestones; champions and drivers; regulatory framework, noteworthy publications; learning and education; measurements and benchmarks; standardised parts and deliverables; technology infrastructure. This model provides insight into the level of BIM application and specific politics and regulations related to BIM implementation within that market and that determines the highest potential level of BIM maturity which can be applied on a certain project on that market.

After the project delivery method, BIM application and the level of maturity are chosen, it is necessary to define the necessary requirements that need to be fulfilled by the participants who will be involved in this project. These BIM requirements can be related to BIM capacities of the organization as well as the personal competences of individuals or to the BIM areas which need to be taken into account when implementing BIM. Individual BIM competences are personal qualities, expert knowledge, and technical capabilities a person needs to have in order to realize a BIM activity or create a BIM product. These qualities, activities, or final products, must be measurable in terms of performance standards and available to be obtained or improved through education, training and/or development (Succar, Sher and Williams, 2013). Individual competencies within an organization represent the base of the capacities of the organization. Standardisation and defining BIM competences significantly contribute to reducing inefficiencies between teams and organizations. By analysing the necessary competencies of individuals, the authors of this paper have aimed to develop curriculums for new courses that will enable students to obtain and develop the necessary knowledge and skills.

According to (Succar, Sher and Williams, 2013), individual BIM competences can be divided into three categories, as explained in Figure 5.

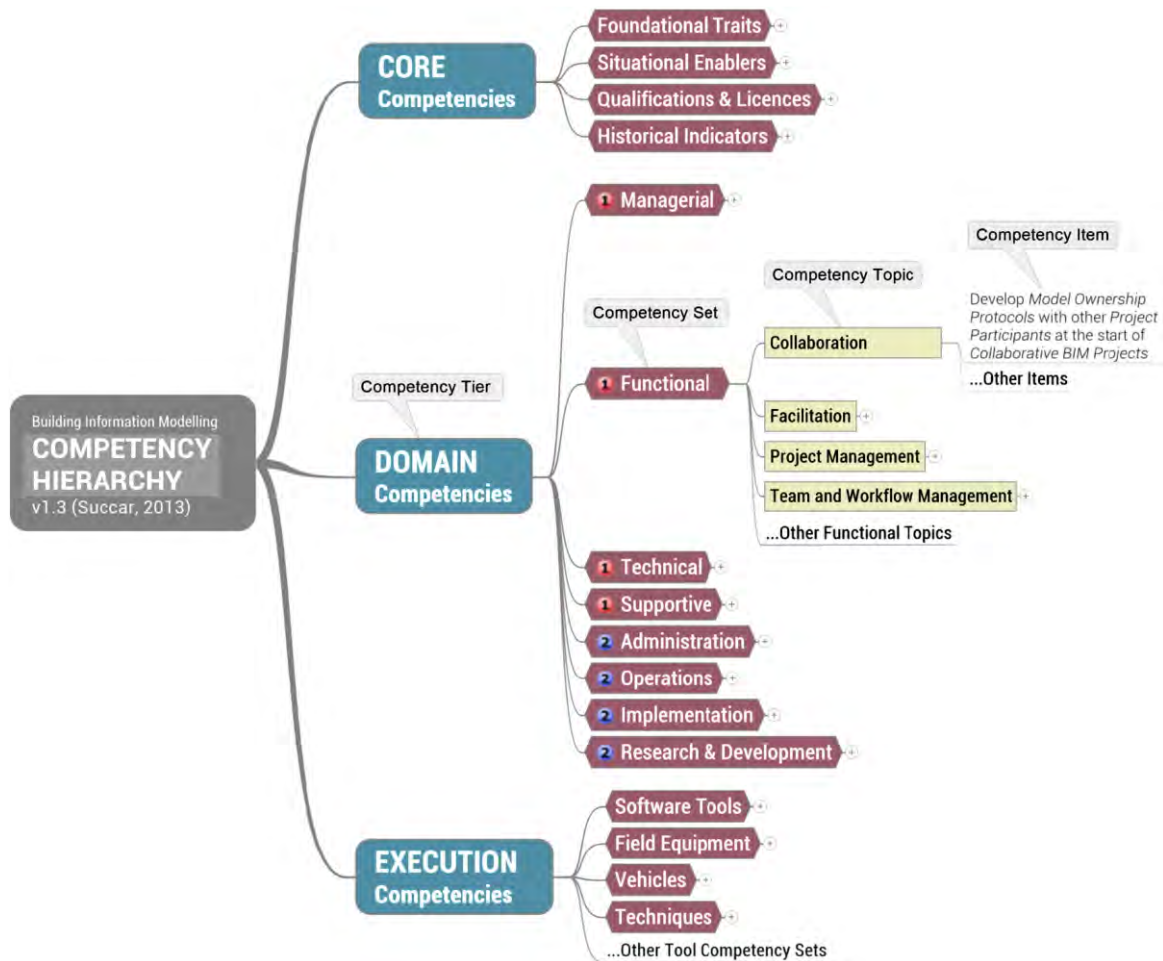


Figure 5. Individual BIM Competencies (Succar, Sher and Williams, 2013)

#### 4.3 Comparative analysis of BIM software to be implemented in the new curriculums

As mentioned above, a part of developing curriculums was a comparative analysis of BIM software for project management in construction industry available in Serbia. The first step was defining the criteria which was to ensure easier identification and recording of properties and functions of the software being analysed. The criteria were defined so as to encompass most of the BIM processes during which the use of software in question is possible. The defined criteria were classified in several groups related to different processes that the software in question supports. There were five groups of criteria: General criteria, 3D Coordination, Quantity Take-off, 4D Visualization and Scheduling, 5D Estimating and Budgeting. General criteria refer to questions of interoperability, software interface, possibility of multiple users, manipulation of model elements. The other criteria groups refer to the scope of applications in

various processes covered by the specific software. Results obtained by this analysis are shown in Table 1.

The pieces of software chosen for analysis were: *Bexel Manager* which is developed by Serbian company Bexel Consulting Ltd, *Synchro PRO 5.1* and *Autodesk Navisworks Manage 2016*. All the chosen software represents collaborative tools which can be applied by users from various disciplines and in different project types.

Table 1. Comparative analysis of BIM software for project management in construction industry available in Serbia

Software type	1.1. Inter-operability	1.2. Multiple users	1.3. Manipulation of model elements	2.1. Clash detection	3.1. Quantity Takeoff	4.1. Schedule Import/Export	4.2. Schedule creation	4.3. Task Resources
Bexel Manager	✓	✓	✓	✓	✓	✓	✓	✓
Synchro Pro	✓	X	✓	✓	X	✓	✓	✓
Navisworks	✓	X	✓	✓	✓	✓	✓	X

Compared to all other software analysed, *Bexel Manager* represents a unique, most comprehensive solution which covers all the current BIM processes which are recognized as necessary for adequate application of BIM technology for construction project management. The others are all focused on a smaller number of specific processes. So, for example, *Synchro Pro* is focused primarily on the process of 4D planning while the *Navisworks'* capacities are based mostly on Clash Detection.

This analysis served for selection of software which will be applied in practical teaching for students performed in ICT labs. *Autodesk Revit* is chosen as a software for development of a building's model at the course "The basics of designing by applying BIM technology".

#### 4.4 Results and goals of studying BIM

The first course, *The basics of designing by applying BIM technology* is lectured in the last, fourth year of bachelor studies. The course is held in the summer term, simultaneously with preparing the final thesis; it has a class load of 2 lectures and 2 practical exercises; according to the current accreditation it is worth 5 ECTS. As it was pointed out earlier, according to the current programme, that is the only ongoing course at the Faculty of Civil Engineering while the course *BIM in Construction Project Management* is being prepared.

Through educating students on BIM theory, the goal of the subject is to overview all the most relevant aspects of a complex digital model of a construction object and all the relevant impacts this kind of a model has on project realization. For that purpose, the subject is divided into the following key units:

- 3D component modeling;

- Process modeling;
- Compatibility;
- Standards.

Through this content, the students are lectured how to analyse the process and through that, how to define the information needs during the realization of the entire process. Then, through detailed examination of the 3D information model of the building, which, in addition to the geometrical data contains semantics, the students are taught to recognize the information which can be automatically obtained from such a model, independently from a specific application (Petronijević et al., 2018). It should be pointed out here that the students at the Faculty of Civil Engineering in Belgrade obtained the necessary knowledge in object-oriented programming in previous courses which, on one hand, makes it easier for them to understand the concept of the object-oriented model (BIM model) and makes them more efficient in creating BIM models. On the other hand, there was significant interest by students in defining the needs for improvement and adjustment of existing software tools via numerous modules aiming for better automation of the processes on the projects.

Above all, the greatest interest expressed by the students was for learning various software packages. It is known that construction, when compared to other industries, is very fragmented and experts from various fields are involved in construction projects realization. This characteristic of civil engineering is reflected in software packages following that diversity and the large number of various software available.

Student versions of these software packages are constantly being tested by students who are increasingly exploring the capabilities of different software. However, here a question of transferring a model between different software is raised and that is one of the current challenges for the software manufacturers as well. For that reason, as previously mentioned, one section of the training will deal with software compatibility. In addition to learning the concept, the students will be studying the neutral format that is currently the most wide-spread, Industry Foundation Classes (IFC).

At the end, it should be noted that the practical exercise classes for this subject focus on practical application of the chosen software (*Autodesk Revit*). Students are divided into teams and each team is tasked with realization of one model of a building and with sharing among themselves the roles of participants in creating this model.

The new course *BIM in Construction Project Management*, that is planned to start in September 2019, has a goal of increasing individual competences in BIM applied in different areas of construction project management (especially scope, cost and time management) and in different construction and civil engineering areas (namely residential/office buildings and infrastructure). It will be held as an obligatory course for the master level of studies in Management, Technology and Informatics in Civil Engineering and an elective course on the master level of studies in Structural Engineering as well as Roads, Railroad and Airports Engineering.

The course syllabus will cover the following topics:

- Definition of BIM and its relation to Project Management areas
- Life cycle phases of buildings/infrastructure
- BIM application throughout life cycle phases
- BIM software in construction management in the building and infrastructure sector
- BIM supported scope, time and cost management

The exercises will consist of practical lab work on applying two software packages:

- Bexel Manager and
- Autodesk package, consisting of:
  - Revit Structure and Architecture - for manipulating with models of buildings and continual study of topics covered in the first BIM course;
  - Civil 3D – for learning basic modeling of line infrastructure, especially roads, and
  - Navisworks – for connecting built models with time schedules and BoQs developed and covered both theoretically and practically in other courses and explore opportunities for visualisation and visual static and dynamic reporting

The guest lectures are also foreseen, where leading industry practitioners will present case studies of BIM implementation and specific aspects and challenges of the processes and tools applied.

The course is designed to blend into the master programme as students will explore connections of topics covered in this course with outcomes received from the undergraduate studies, as well as leverage on topics covered in other master courses, such as Risk and Sustainability Management in Construction, Value Engineering, Advanced Planning Methods, etc.

## **5. Conclusion**

Considering that it has been noted that BIM had reasonable success in all countries that introduced BIM implementation in their legislation, BIM becomes a standard all over the world. The Department for Construction Project Management at the Faculty of Civil Engineering in Belgrade recognized the significance of adequate students' education in the field of BIM. In order to keep the pace with everyday demands of industry, the Department has introduced BIM in lecturing on undergraduate level of studies in Management, Technology and Informatics in Civil Engineering. The second part of student's BIM education is planned to start very soon on the master level of studies. The Department for Construction Project Management also tends to initialize BIM education on other modules at the Faculty of Civil Engineering. Having in mind the project goals (cost, time and quality) and benefits of BIM application, it is important to follow the newest developments of BIM in order to implement them during the education process and to develop new curriculums and improve the existing courses.

## Acknowledgement

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# Technological Innovation in Architecture and Engineering Education - An Investigation on X, Y and Z Generations in Turkey

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## Abstract:

The developments in technology have caused many radical changes in the curriculum of architecture and engineering disciplines. At the same time, generations and their personal characteristics are in continuous change that is shaping newer education techniques. In this context, this study is aimed to compare the educational perceptions of generations X, Y and Z for technological advancements. For this purpose, a literature review concerning the technological advancements in education and characteristics of X, Y, and Z generations are demonstrated. Then, a survey was conducted on 160 respondents to differ the perceptions in between these generations while considering other educational and social related subjects. Results of this study support that IT-related education is insufficient for the upcoming generations who were born and grew in the digital age. For Y and Z generations, the knowledge level of the innovative construction technologies found relatively lower than the X generation which could be associated with the level of experience. Generation Y is the least satisfied with IT-related lectures and more affected by the movement of sustainability. The perceptions in between the generations are found statistically different. The outcomes of this study are expected to guide professionals in architecture and engineering education to better fulfill the expectations of the upcoming generations.

*Keywords: X, Y, and Z, generation, education, architecture, engineering, SPSS, Turkey.*

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## 1. Introduction

Lately, the construction industry is facing substantial technological transformations that enrich both architecture and engineering curricula. Advances in technology have led to changes in the perception of individuals for education in the construction industry. Relatively new approaches and computer skills are thought in universities to fit the market and employer expectations. Today's graduates need to develop broader perspectives to consider both cost, time and quality constraints with social, environmental and lifecycle related economic factors (Becerik-Gerber *et al.*, 2011, Johnson and Gunderson, 2009).

Education always remains one of the most up-to-date concepts of language and culture (Dogan, 2008) which enhance the construction industry formatively. Education could be defined as the art of raising people for a certain purpose, where changes occur in knowledge, skills, attitudes, and values (Inal, 2004, Fidan and Erden, 1998). Teaching is within the concept of education which could be explained as the work of giving education for a certain purpose



(Sekin, 2013). The teaching process should be compatible with changing student profiles and should develop over time or in other words, different educational needs among generations also should result in different educational models (Bates, 2005). In the theory and practice courses in architecture and engineering education, updates are made and educational tools became more modern (Akrouf and Rouxin, 1999). For example, traditional expression processes have changed in design classes and computer-aided programs are used as tools in the process of visualization. Therefore, the characteristics of different generations influenced architecture and engineering education which led to the introduction of more interactive and collective educational models. However, these models need to be constantly questioned whether they conform to the requirements of the age (Lokce, 2013).

In this study, the concepts of X, Y and Z generations and their characteristics are profoundly identified with literature. Also, architecture and engineering education related studies are examined. The survey is aimed to explore the effect of developing technology on the education of architecture and engineering disciplines with the profiles in X, Y and Z generation students from Turkey.

## 2. Definitions

### *Generation X, Y, and Z*

The rapid changes in the last century have led to the emergence of intergenerational differences. Social, cultural and economic developments have caused each generation to have different perceptions and expectations (Angeline, 2011). In this section, the characteristics of X, Y, and Z generations will be discussed and the changes in architecture and engineering education will be examined as a result of the research model.

Generation X is the generation of individuals born between 1965 and 1979 (Castellano, 2014) which could be called “the transition period children” of Turkey. Like the previous two generations (The silent generation (1925-1945) and the baby boom generation (1946-1964)), this generation has faced economic problems (i.e. oil crises). They show the common characteristics of austerity, high job motivation, industriousness, loyalty and respect for authority (Goksel and Gunes, 2017). However, they have waited for an opportunity for a better future started to use technology as a necessity because of the technological revolution (Senbir, 2004). Zemke *et al.* (1999) argued that the core values of this generation are optimism, personal development in education and health, commitment to authority and diligence.

Generation Y is also called the post-80 generation (Castellano, 2014). The members of this group grew up in a protective and safe environment created by their families resulted in their transition to become self-centered individuals (Cemberci *et al.*, 2014). Generation Y conducts research, question authority, use technology and communicate with the world. They care about entrepreneurship, open-mindedness socialization and success but show impatience as a characteristic at the same time (Tolunay, 2011). This community is technology-friendly, self-centered and more relaxed than previous generations (Senbir, 2004). Their requests for flexible working hours and a comfortable working environment resulting in the design of new space types.

Generation Z or “Instant Online” generation identifies the individuals born after 2000 (Levickaite, 2010). This community is called the new Silent generation (Howe and Strauss 1992) because members of this community will experience individualization and isolation in real life where their virtual relationships could be stronger. Their ability to communicate via virtual platforms prone to lonelier, self-centered and self-conscious lifestyles. This generation could be able to develop their intellectual abilities and research skills quicker than the previous generations due to easier access to a variety of knowledge resources (Akdemir and Konakay, 2014). Oz (2015) featured the characteristics of these three generations given in Table 1.

Table 1. Characteristics of X, Y, and Z generations (Oz, 2015)

Generation X	Generation Y	Generation Z
Sensitive and respectful to authority	Devoted to their independence	An integrated life with technology
Develop a sense of belonging to the workplace	Like to spend time individually	Don't have a sense of belonging to the workplace
Realistic	Familiar with technology	Doesn't like to spend time outdoors
Use technology as a necessity	Multiprocessing abilities	Creative
Shopping enthusiast	Impatient	Love being alone
Work to live	Attach Importance to Status	Conscious and confident of their aims

Today, due to the rapid increase in knowledge and as a result of construction industry skills becoming technology-oriented, researchers study on the IT to support educational purposes (Wang *et al.*, 2018, Wong *et al.*, 2011, Heinecke *et al.*, 2001). In response to the different demands of the new generations, teaching programs are found insufficient, which suggests that educational environments and programs need to be updated (Somyurek, 2014). The technology-oriented life of the generations Y and Z create the demand for more interactive and technology-based education in architecture and engineering from the previous generations.

### *Education and Technology in Architecture and Engineering*

Architecture and engineering education is a multidisciplinary system that focuses on both design and calculation in order to create a genuine environment which is evolving and changing by the motion of emerging technologies.

The formal education in architecture has started with Beaux-Arts in the 19<sup>th</sup> century and the most radical change is experienced with the Bauhaus education established by W. Gropius (Lokce, 2002). Information technology (IT) was introduced in architecture in the 1960s, but the introduction of these technologies to architecture education has extended to 1980s (Rzazade, 2018). In Turkish civil engineering curriculum, IT related education is initiated with the first lectures of “Electronic Calculation” in Istanbul Technical University (ITU) Civil Engineering faculty by Ozmen in 1968. Later in 1971, Citipitioglu started giving a lecture named “Computer Methods in Civil Engineering” in Middle East Technical University (Ozmen, 2011). Under the influence of these developments, computer-aided design, energy conservation, and sustainability-related software, as well as Building Information Modelling (BIM), have started to spread to architecture and engineering curriculums. Through these

trainings, architecture and engineering students were able to experience computer-aided modeling. Today, lectures concern 3D modeling, creating animations, virtual reality, and parametric design applications. The number of programs that enable students to establish relations between forms and the mathematical and geometric transformations of these forms (parametric design) has increased. For example, Rhinoceros is Nurbs-based Computer Aided Design (CAD) software designed for 3D modeling and prototyping which enables information exchange between different programs; such as Grasshopper is incorporated into the Rhinoceros program which enables algorithmic modeling by using modeling tools. Since the operations used in Grasshopper are mathematical, the interface of Rhinoceros is used to visualize the changes (Aydin and Yaman, 2015). However, it should be noted that these programs used in architecture converts the processes with different and easier interactions in architecture education but do not produce the whole design content. The developments in technology also provide variety to students' perceptions and experiences; multi-sensory and interactive education addressing the different sensory organs ensures the learning rather than only visual and verbal communication (Madi, 2011).

A project could only be completed with the unity of knowledge and imagination, where technology has become an essential part of the equation. The construction industry needs an integrative education system by its project-based nature. Upcoming needs and growing project sizes in the construction sector necessitate different disciplines to work together in harmony (Ozturk and Eraslan, 2018). The development of interactive education has also facilitated interdisciplinary work. Lately, architecture and engineering students emphasized greater importance in understanding project management with different disciplines by taking advantage of technology (Ofluoglu, 2017). The interdisciplinary work of the students become more likely to understand the perspectives of different disciplines in the future. In this respect, BIM has exhibited a prominent role in picturing the collaboration of the architecture and engineering disciplines. The system covers all of the processes of a project such as design, 3D modeling, scheduling, resource management, construction and maintenance (Ofluoglu, 2016). BIM workshops are established in various universities such as; Pennsylvania State University, University of Illinois, University of Florida, University of Kent State, University of Salford and Sydney University that led students from different undergraduate programs to study jointly. One similar workshop is also held in Turkey with a competition called "Design Together" (Alkawi, 2016). In the country, BIM related education opportunities are still limited; ITU and Bogazici university have BIM related educations, respectively; BIM Expert certificate program, and the education of applied BIM processes in construction projects.

### **3. Literature Review**

#### *3.1 Education in Generations X, Y, and Z*

In this section, literature research on the educational differences of X, Y, and Z generations is conducted.

Koknel (2017) emphasized the importance of the difference created by the cultural environment of the students in order to establish the content of curriculum programs and emphasized the characteristics of X, Y and Z generations. It has been indicated that the majority

of generation Y is unemployed and tends to live abroad where 20% has been graduated from higher education. The author advice that education of previous generations should be translated carefully according to the age, intelligence, perception and memory skills of students from generation Z. He argued that the X and Y curriculum would be applied to Z generation but that the age, intelligence, perception, and memory of the students who would receive education for successful learning theories should be taken into consideration (Koknel, 2017).

Seymen (2017) examined the characteristics of Y and Z generations and mentioned that no updates were made in the 2014-2019 strategy report published by the Ministry of National Education and TUBITAK Vision 2023 report. Seymen stressed that research on the next generations should be carried out and education should be adapted to the changing needs.

Cetin and Karalar (2016) discussed the notion of a career with 1875 students from Edirne and Istanbul. According to the research, 65,4% of X, 78,8% of Y and 63,4% of Z-generation students have the perception of self-management. The perception of movement according to generation type and values is 57.3% in X, 54.6% in Y and 44.6% in Z generation students. Generation Z has higher movement according to values, physical mobility and self-management perceptions are than generation X. Protean and unbounded career perception is greater for generation Y students than the other generations.

According to an infographic report by Marketo (2014), generation Z knows how to self-train and access information. In the US, 33% of the Z generation follows lessons online, 20% read lessons from the tablet, 32% work online with classmates and 52% use social media for research. However, one interesting statistic from this study revealed that the average time of attention for a person in Z generation is only 8 seconds. According to the research, generation Y prefers to communicate with written text and sharing while generation Z prefers visual communication and creating.

Lisboa and Coutinho (2012) stated the obstacles faced in that rapid developments in technology and social changes that emerged in different generations. Different generations of different characteristics sharing the same spaces in the education expose deficiencies. This situation requires different generations with various characteristics to accept the same curriculum together. Authors stressed the necessity of implementing different strategies in education and training for different generations.

Strauss and Howe (1991) put forward that Z generation students would prefer to be personal and independent in group work. In addition to that, the Z generation is the generation that integrated the concept of entrepreneurship for high school and university curricula. Since they are thought to be more easily adaptable to high technology, they are expected to be more capable but easily bored workers in the future.

All in all, in order for the education to be beneficial to the students at the highest level, the characteristics of the generation and era should be taken into consideration in determining the type and level of education to be given.

### 3.2 Education and Technology in Architecture and Engineering

A literature survey was conducted in order to investigate the effects of developments in IT on architecture and engineering education in this section.

Guney (2015) studied on the benefits and disadvantages of IT for architecture education. The advantages are published as; alternative design creation, easy storage, and sharing, easier communication with other disciplines, ease of revisions, faster design stages, 3D visualization, time-saving features, a better understanding of design, evaluation, and ease of replication. The disadvantages are explained as; higher quality visuals instead of better design, less interaction between students and teachers, inadequate literature research, low-quality design, the negative effects of CAD programs on creativity and technology dependence.

Gul *et al.* (2013) investigated the importance of the models and the IT technologies used in architecture education. The survey was conducted with 213 lecturers and 470 students in Turkey. According to the results of the survey, which included 72 questions for faculty members and 54 questions for students, it is understood that the approximately 45% in the curriculum of architecture schools in Turkey is intended for design related lectures which students predominantly use AutoCAD software. While 30% of the faculty members certify that IT technologies should be used in architecture, 35% disagreed with this view and 35% remained impartial. But 61% of lecturers argued that IT should be used in presentation techniques. 70% of the students were not satisfied with the computer-aided design courses they received and 74% of them argued that the lectures contributed to their development of 3D thinking skills through the use of IT technologies at the university.

Hanna and Barber (2011) conducted an experiment of the computer skills effect on the architecture where 15 students were in the control group and 15 students were trained in CAD software programs for 7 days. After the software education, the developments in concept building, visual quality, and presentation techniques were recorded as positively improved for the trained group.

Mertol and Yılmaz (2011) argued that civil engineering education should be updated with changing developments according to technology. The implementation of active learning techniques in civil engineering education depends on the efforts of the instructors, where 21 different technique from Moran (1997) is summarized for the Turkish case. They expected that the digitalization related changes will be more available with the well-trained teaching staff that will increase the interest in classes and eases the remembering process for students.

Ozmen (2011) argues that it is the right thing to teach the foundations of the programs such as AutoCAD in civil engineering education but, he concerned that the courses in which vocational software programs are thought are not efficient and effective for undergraduate students. The author stated that these software-oriented courses should be given at the master's level in detail and the perception of the results from the computer is indisputably accurate is not always consistent.

Birinci and Koc (2007) argued that civil engineering education should be updated in Turkey because of the lack of equality between Turkish universities and that the variety of

education is not equivalent to developed countries. In addition, they argued that students should be able to solve simple problems with their own programming skills in bachelor curriculum which was in contrast with Ozmen's arguments (2011).

Pektas and Erkip (2006) carried out a survey to discover the male and female difference in the use of IT technologies at architecture education with interior architecture undergraduates of Bilkent University. According to the results, male students were statistically significantly eager to use computers in design, where female students were less enthusiastic. Female respondents are found to be more reliant on the instructors, however, there were no substantial correlations between both female and male students' attitude toward computer usage in design and their perception of the instructors' attitude.

In this context, it can be concluded that IT and CAD have different effects with different groups in the literature. The common point emphasized in the studies is that while designing and implementing curriculum, student and generation backgrounds, capacities and future expectations should be carefully considered.

#### **4. Methodology**

In this section, respondents from 5 metropolitan regions of Turkey; Istanbul, Sakarya, Bursa, Antalya, and Eskisehir who are the architectural and engineering students as well as architects and engineers that have completed their education have been evaluated in terms of their perspective on the technology in education. Various evaluations are given according to different cohort groups. The respondent profile could be followed in Table 2.

##### *4.1 Sampling Process and Preliminary Study*

The main group of the research is the students of the Y generation who live in Istanbul. As a sampling method, the easy sampling method was chosen. A total of 29 questions were asked in the survey conducted with 160 people. Before the final version of the survey was established, pilot interviews with the three respondents belonging to X, Y and Z generation showed that the survey is clear with the statements and the connections between IT and education is relevant. Opinion questions asked during the work to the respondents to improve the survey.

##### *4.2 Data Collection and Analysis Tool*

The research was carried out through a comprehensive data collection process. This study, which was created by combining qualitative and quantitative data, was prepared to analyze the current state of education and how the technology concept in architecture and engineering education in Turkey has changed for generations. A total of 400 online surveys were sent out in April 2019. At the end of the survey closure, 160 responses were received which represents a response rate of 40%. The questionnaire was used as a data collection tool and the questionnaires were sent to the participants via online forms. These questionnaires were prepared according to the Likert scale (1-5) and analyzed using SPSS 25.0. The survey starts with questions that include general information such as the date of birth, gender, educational status, profession, monthly earnings and questions to measure the interaction of the participants

with the internet. Then the participants were asked about the use of technology in architecture and engineering education.

The values of generation type, monthly salary, internet use per day, membership to social media platforms, time spent on social media, satisfactory level of education, satisfied respondents with information technology courses at school, respondents with craft education, number of group studies in bachelors, and remaining Likert questions are tested with skewness and kurtosis, where values are remained in between  $\pm 1,5$  (Tabachnik *et al.*, 2007) representing the adequacy for statistical consistency. Also, Kolmogorov-Smirnov tests are performed where results were found satisfactory according to Lilliefors (Lilliefors, 1967). Therefore, our data could be classified as normally distributed and parametric tests are applied.

Table 2. Profile of Respondents

Respondents	Sub-Group	n	%	Mean	Median	St. Dev.
Generation	1965 - 1980 (X)	20	12,5	-	-	-
	1980 - 1999 (Y)	109	68,1			
	2000 - Today (Z)	31	19,4			
Sex	Female	78	48,8	-	-	-
	Male	82	51,2			
Occupation	Student	123	76,9	-	-	-
	Employee	27	16,9			
	Student and Employee	10	6,3			
If student, the level of studies	1st Class (1)	28	17,5	2,881	3	1,982
	2nd Class (2)	7	4,4			
	3rd Class (3)	36	22,5			
	4th Class (4)	33	20,6			
	Extension Student (5)	10	6,3			
	Master Student (6)	18	11,3			
	Ph.D. Student (7)	3	1,9			
Monthly income (Total of scholarships and pocket money for students)	0-500TL (%15 tax bands) (1)	34	21,3	3,256	3	1,874
	500-1000 TL (%15 tax bands) (2)	38	23,8			
	1000-1500TL (%15 tax bands) (3)	24	15,0			
	1500-2000TL (%20 tax bands) (4)	17	10,6			
	2000-3333TL (%20 tax bands) (5)	16	10,0			
	3333-12333TL (%27 tax bands) (6)	26	16,3			
	12333- over (%35 tax bands) (7)	5	3,1			
Internet usage per day on tablet, mobile and PC	Less Than 1 hour (1)	6	3,8	2,688	3	0,818
	1-3 hours (2)	68	42,5			
	3-5 hours (3)	56	35,0			
	More than 5 hours (4)	30	18,8			
Use of social media (Facebook / Instagram / Twitter)	I dont use social media platforms (1)	8	5,0	2,838	3	0,861
	I'm using one platform (2)	50	31,3			
	I'm using two platforms (3)	62	38,8			
	I'm using three platforms (4)	40	25,0			
Hours per day spent on social media	I dont use social media platforms (0)	8	5	2,906	3	0,963
	0-1 hour (1)	45	28,1			
	1-3 hours (2)	72	45			
	3-5 hours (3)	26	16,3			
	5-7 hours (4)	7	4,4			
	More than 7 hours (5)	2	1,3			

Tracking technological developments in Edu.	Yes	101	63,1	-	-	-
	No	59	36,9			

## 5. Results

The analysis of the survey data revealed that the mean value of the satisfaction from architecture and engineering education is 3,13 and the standard deviation is 1,029 where “Moderately-I am familiar with my profession thanks to my education” answer was the most common answer. IT related courses are mostly found unsatisfactory (67%) where over 81% of respondents are taken computer-aided design lectures. Over 58% of respondents prefer both traditional and computer-aided design solutions for design courses. Remaining statistics could be followed from table 3.

Table 3. Answers of Respondents According to Generations

Answers	Sub-Group	n	%	Mean	Mean X	Mean Y	Mean Z
Satisfactory level of overall education	Insufficient (1)	10	6,3	3,13	4,150	3,028	2,839
	Less than enough (2)	31	19,4				
	Moderately (3)	61	38,1				
	Sufficient (4)	44	27,5				
	Very Sufficient (5)	14	8,8				
Satisfactory level of courses related to IT	Satisfied (1)	36	22,5	2,194	2,350	2,239	1,935
	Neutral (2)	67	41,9				
	Not Satisfied (3)	57	35,6				
IT Development used in Lectures (Frequency)	Never (1)	8	5,0	3,200	2,650	3,367	2,968
	Rarely / Around 10% (2)	39	24,4				
	Sometimes / Around 50% (3)	43	26,9				
	Frequently / Around 75% (4)	53	33,1				
	Always (5)	17	10,6				
Computer Aided Design Courses	Taken (1)	130	81,3	1,188	1,450	1,092	1,355
	Not Taken (2)	30	18,8				
Design Tools for Design Classes	AutoCAD / Revit etc. software	30	18,8	2,400	2,350	2,523	2,000
	Traditional methods (Paper/pencil)	36	22,5				
	Both	94	58,8				

Also, the importance levels are examined for education in architecture and engineering. Problem-solving abilities is the prominent feature found to completely comprehend the education for architecture and engineering that could be followed from the figure below.



Generation Z has shown greater importance on design, creativity, and imagination as well as problem-solving capabilities in education than the previous generations. The result of lower knowledge levels of newer technologies in the industry could be associated with the age of generation Z who are still young and under education.

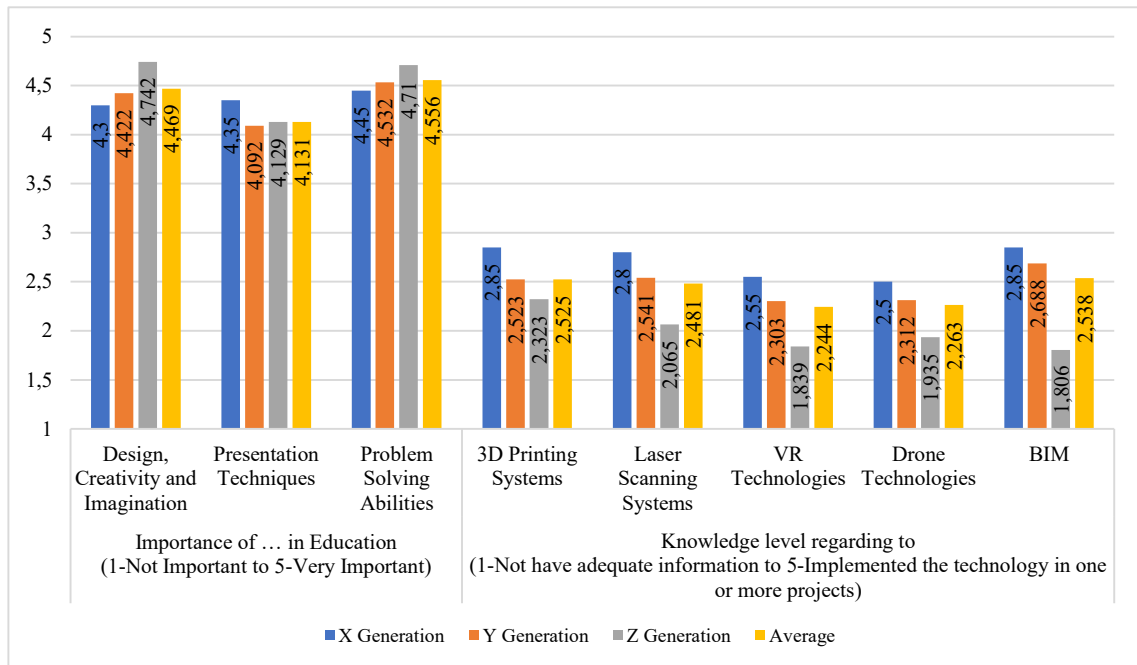


Figure 1. Importance and Knowledge Level of Some Techniques/Technologies According to Generations

One interesting result is that generation X and Y have responded that vision is superior to other senses, however, generation Z has identified similar and even greater importance on hearing. Also, the unfamiliarity to the architectural movements of generation Z could be associated with their age and the beginning of their bachelor studies. Modernism and sustainability are found as the prominent movements for the respondents on average. The remaining statistics regarding the average results of generations could be followed from figure 2.

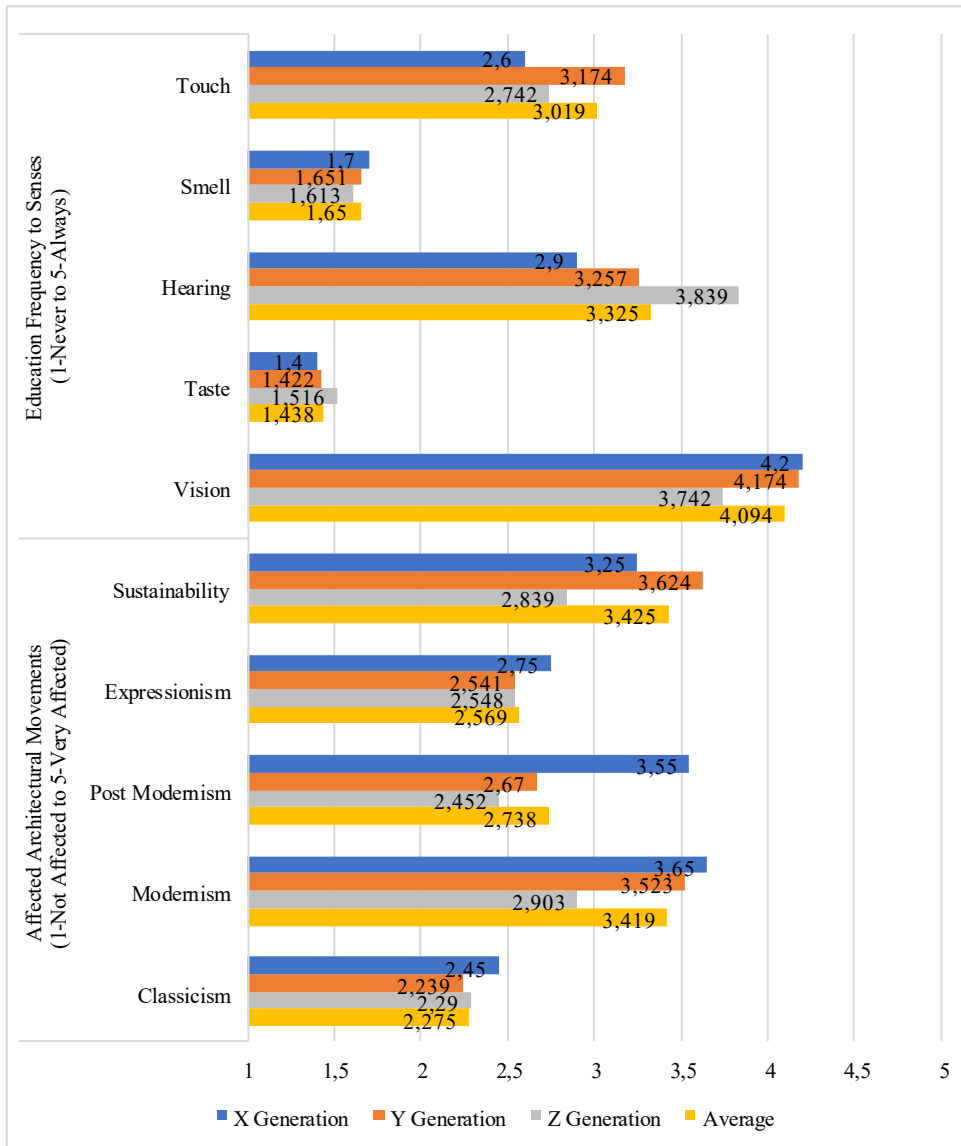


Figure 2. Education Frequency to Senses and Affected Architectural Movements throughout the Education

It is the generation Z that agrees the most that technology will guide architecture and engineering education in the future, where generation X is more conventional with this insight which suits with the characteristics mentioned by Oz (2015). Also, related to the upcoming strengths of computer-aided design such as the elimination of the human factor is mostly appreciated by generation Z, given in table 4.

Table 4. Technology and Education Related Expectations of Generations

Question / Generation		X	Percent.	Y	Percent.	Z	Percent.
Technological developments will lead future of architecture and engineering education	Yes (1)	18	90,00%	104	95,41%	31	100,00%
	No (2)	2	10,00%	5	4,59%	0	0,00%
Computer aided design will eliminate human factor in design	Yes, it will (1)	4	20,00%	29	26,61%	9	29,03%
	No, it will not (2)	5	25,00%	10	9,17%	3	9,68%
	The human factor will always remain, but its share will be reduced (3)	11	55,00%	67	61,47%	18	58,06%
	Don't know (4)	0	0,00%	3	2,75%	1	3,23%

As the generations are examined in over two categories, instead of t-tests, ANOVA tests are conducted. After the tests of homogeneity of variances, one-way ANOVA's post-hoc tests are decided. Moreover, when the homogeneity tests are over 0,05 Tukey and Scheffe tests are applied and if its below 0,05 Games-Howell tests are conducted.

According to table 5, generation X have statistically more affected by the post modernism movement and more satisfied with their education than generations Y and Z. Generation Y is the least satisfied group with the level of courses related to IT. Generation Z claimed that they have more study opportunity in a multidisciplinary team in their bachelor studies. Besides the table, respondents with the highest salary levels gave higher importance to both traditional techniques and IT in design courses rather than the other respondents.

Table 5. ANOVA Results (Tukey Tests)

Code	Dependent Variable	Generations to Compare		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
		First	Second				Lower Bound	Upper Bound
1A	Satisfactory Level from Education	X*	Y	1,12248*	0,249	0,000*	0,502	1,743
1B	Satisfactory Level from Education	X*	Z	1,31129*	0,291	0,000*	0,603	2,019
2A	Satisfactory level of courses related to IT	X*	Y	,35826*	0,117	0,016*	0,062	0,654
2B	Satisfactory level of courses related to IT	Y	Z*	-,26310*	0,092	0,018*	-0,487	-0,039
3	IT Lead Studies (Frequency)	X	Y*	-,71697*	0,257	0,016*	-1,324	-0,110
4	Level of BIM Knowledge	Y*	Z	,88162*	0,285	0,007*	0,206	1,557
5	The Type of Lectures (Mostly)	X	Z*	-1,05806*	0,330	0,005*	-1,838	-0,278
6	Multidisciplinary Study Opportunity in Bachelor	X	Z*	-,39194*	0,135	0,017*	-0,722	-0,061
7	Craft Education	X	Z*	-,64677*	0,166	0,001*	-1,053	-0,241
8	Sustainability Education	Y	Z*	-,40722*	0,089	0,000*	-0,622	-0,192
9	Technique Preference in Design Courses	Y*	Z	,52294*	0,152	0,003*	0,156	0,889
10	Internet use Per Day	Y*	Z	,48002*	0,136	0,002*	0,154	0,806
11	Modernism Movement	Y*	Z	,61971*	0,261	0,049*	0,002	1,238
12	Post Modernism Movement	X*	Y	,88028*	0,299	0,010*	0,173	1,587
13	Post Modernism Movement	X*	Z	1,09839*	0,352	0,006*	0,265	1,932
14	Sustainability Movement	Y*	Z	,78514*	0,294	0,028*	0,072	1,498

Table 5 is coded in order to be followed easier and this paragraph aimed to explain this table respectively. The (\*) sign at the groups represent the superiority over the compared one. Generation X are more satisfied with their education than newer generations. One interesting result from table 5 is the satisfactory levels of IT related courses are higher than the generation Y for the remaining generations. However, generation Y claimed that the IT-related courses are more frequent; where this situation could be explained by the inefficiency of these courses. Level of knowledge difference of Y and Z could be interpreted with the experience of the industry. Type of lectures is mostly “design” in generation X, where “CAD” lectures are in majority in generation Z. Moreover, generation Z put forward their greater opportunity to study the craft and with other professions than generation X. Also, sustainability-related education is applied more in generation Z than Y. Because of the freshman year of generation Z, technique preference in the design classes is traditional tools such as hand-drawing, where generation Z preferred both traditional methods and CAD solutions. Internet use was statistically higher for generation Y than Z, but averagely in between 1 to 3 hours. Generation Y has greatly affected by modernism and sustainability movement than Z, where generation X has affected by post-modernism than newer generations.

Furthermore, the regression tests are conducted. Therefore, a satisfactory level of education inversely correlated with the generations. The following equation could be derived;

$$(0,103) \times (\text{GenerationLevel}(X,Y,Z)) = 4,344 + (\text{SatisfactoryLevelofEducation}) \times (-0,586) \quad (1)$$

The t-test is conducted because of the comparison between sexes. The following table (6) explains that there are statistically meaningful differences in the given dependent groups. Female respondents gave statistically higher emphasize in each dependent given below. Apart from this comparison, t-tests are applied for the architecture and engineering students. Engineering students who study at public universities and private universities have a statistically significant difference in a satisfactory level of their education; public universities have higher satisfaction levels. On the other hand, architecture students who are studying in private universities have a higher percentage of courses benefitted from IT than public university students. That is to say, even though the IT usage level is higher in private universities, the efficiency of the related education is not satisfactory.

Table 6. Independent Sample t-test Results

Dependent	Group 1	Group 2		Levene's Test		Sig. (2-tailed)
				F	Sig	
Education Applied to Sense of Vision	Female*	Male	Eq. var. as.	2,148	0,145	0,001*
			Eq. var. not as.			
The effect of Modernism Movement	Female*	Male	Eq. var. as.	3,172	0,077	0,001*
			Eq. var. not as.			
The effect of Post Modernism Movement	Female*	Male	Eq. var. as.	0,835	0,362	0,028*
			Eq. var. not as.			
Importance of Presentation Techniques in Education	Female*	Male	Eq. var. as.	3,589	0,06	0,004*
			Eq. var. not as.			
Usefulness of Computer Aided Software in Design Courses	Female*	Male	Eq. var. as.	38,6	0	0,001*
			Eq. var. not as.			

## 6. Conclusions

Means and methods of construction have changed drastically with the technological developments. This change also affects the architecture and engineering curriculum. This study explained the literature for the characteristics of generations X, Y and Z while giving information about the technological advancements in architecture and engineering curriculum. The results of this study indicated that generation X has the greatest knowledge of innovative technologies and satisfaction from education levels. Members of Generation Y is the least satisfied with the content of IT-related courses. Generation Z believed the most that technology will guide architecture and engineering education in the future and computer-aided design is going to replace the human factor. Engineering and architecture students from public schools have higher satisfaction levels of education than students from private universities. Also, satisfactory levels of education found inversely correlated with the newer generations in Turkey. The outcomes of this study are expected to guide professionals in architecture and engineering education to better address the expectations of upcoming generations. Future studies would have a broader perspective for correlations in between the facts that have caused the differences and validate the findings in larger and different samples.

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# The Triangle of Trust: The Irreducible Imperative for Project Team Success

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## Abstract:

This paper reviews relevant literature to crystallize the essence of trust in high-performing project teams for project success by creating a ‘Triangle of Trust’ bounded by: (1) Reliance, (2) Risk, and, (3) Beneficence. Thus, the Triangle of Trust is examined for its robustness and impact in dynamic and complex project environments, infused with Emotional Intelligence (EQ), and championed as the irreducible imperative for project team success. The essentially self-directed project team is characterized herein by interdependence among the team members with “dense, reciprocal ties” (Powell, 1987:76) underscoring the Social Exchange Theory. Interdependence is an important aspect of high levels of ‘optimal trust’ as theorized by Wicks, Berman, & Jones (1999), and as applicable to the dynamic nature of the triple factors of reliance, risk, and beneficence working together. Optimal trust is therefore contextualized to the environment of high-performing project teams as reliable, risk-prone, and robust entities. This optimality is founded upon Aristotle’s ‘golden mean’ principle for human excellence that cautions against extremes (Aristotle, 1996). Such pragmatic-philosophical underpinnings of trust are largely unexplored areas of research (Wicks, et al., 1999), that this paper will delve into. From the springboard of Social Exchange Theory that explores horizontal interactions among team members and the Leader-Member Exchange (LMX) Theory that examines the vertical, dyadic relationships between the project team leader and individual team members, this conceptual paper investigates both the philosophical and practical boundaries of trust for it to be optimally effective in a dynamic project team setting as an imperative for project success.

*Keywords:* Triangle of Trust; Emotional Intelligence (EQ); high-performing project team; Social Exchange Theory; Leader-Member Exchange Theory (LMX); optimal trust; project success

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## 1. Introduction

This conceptual paper reviews relevant literature to crystallize the essence of trust in high-performing project teams for project success by creating a ‘Triangle of Trust’ dynamically bounded by: (1) Reliance, (2) Risk, and, (3) Beneficence. Thus, the Triangle of Trust is examined for its robustness and impact in volatile and complex project environments, infused with Emotional Intelligence (EQ), and championed as the irreducible imperative for project team success. From the springboard of Social Exchange Theory that explores horizontal interactions among team members and the Leader-Member Exchange (LMX) Theory that examines the vertical, dyadic relationships between the project team leader and individual team members, this paper investigates both the philosophical and practical boundaries of trust for it to be optimally effective in a dynamic project team setting as an imperative for project success.



### *1.1 Definition of Trust*

Trust is a key socio-economic concept that plays an important role in many situations ranging from interpersonal relationships to transactional, economic exchanges (Miller & Mitamura, 2003). It is applicable to the economic concept of transactions and benefits. Trust is based on the reliance of one party (trustor) on the actions of another party (trustee), with the expectation of a positive or beneficial outcome. It is also dependent on neuro-biological triggers and responses between individuals. The trustor and trustee form a relationship based on risk and vulnerability on the part of the trustor, and trustworthiness and fidelity on the part of the trustee. Thus, trust may or may not bear fruit or be justified: it is predicated on the philosophical concept of ethics and the pragmatic elements of risk, reliance, fairness, benevolence, and vulnerability. In fact, trust is a universal concept that cuts across individual, group, organizational, societal, and global lines.

### *1.2 Levels of Analysis*

The concept of trust has been studied at various levels of analysis: individual (Kramer, 1996; Baier, 1986), dyadic (Schoorman, Meyer, & Davis, 1996), group (Kramer & Tyler, 1996; Larson & LaFasto, 1989), and inter-firm (Currall & Inkpen, 2002). At the highest levels of analysis, trust lowers mediating agency and transaction costs for firms (Jones, 1995; Frank, 1988). However, at the inter-firm level, trust can tend to become impersonal, legalistic, and even ineffective (Argyris, 1994; Donaldson & Davis, 1991; Granovetter, 1985; Sitkin & Roth, 1993). At the individual level, on the other hand, trust can be too subjective and idiosyncratic. Thus we see that trust is perceived with diverse lenses at various levels of analysis.

### *1.3 Trust Across Disciplines*

It is not surprising therefore that the concept of trust has attracted research attention across several disciplines such as: team dynamics (Lawler, 1992); leadership (Atwater, 1988); game theory (Milgrom & Roberts, 1992); communication (Griffin, 1967); and, human resource management (Cummings, Blumenthal, & Greiner, 1983; Taylor & Davis, 1989). This paper will focus on the team dynamics aspect of trust, specifically in the environment of a major or mega project. Salient concepts such as Emotional Intelligence (EQ), the dichotomy between trust and distrust, optimal trust, and other literature evidence are drawn upon to support the creation of a Triangle of Trust comprising Risk, Reliance, and Beneficence constituting the soft skills that are imperative for high-performing project teams to achieve project success. Theoretical underpinnings are limited to the Social Exchange Theory for horizontal relationships among team members, and the Leader-Member Exchange (LMX) Theory for vertical, dyadic relationships of trust between the project leader and individual project team members.

### *1.4 Trust and Teamwork*

This paper focuses on the project *team* (group) level of analysis (Lipnack & Stamps 1997; Jarvenpaa & Ives 1994), a project team being a temporary organization whose members may have never worked together before, and who may not expect to be working together again.

Such an environment presents a real challenge to trusting relationships between team members of a goal-oriented, risk-prone, and resource-constrained project. It is hypothesized that the interdependence, intimacy, and social influence actuating productive project teamwork raises trust to its highest levels of action and fruition. Indeed, the emergence of self-directed teams, and reliance on empowered members, has greatly increased the importance of trust. This is partly because control mechanisms are reduced or removed through enhanced trust—concurrent with greater interaction, team dynamics, and productivity (Golembiewski & McConkie, 1975; Larson & LaFasto, 1989).

## 2. Literature Review

Despite its importance, trust has been widely quoted as an “under-theorized, under-researched, and, therefore, poorly understood phenomenon.” (Child, 2001:274, as quoted for example, in Bijlsma-Frankema & Wolthuis, 2005). This paper contends that though there has been little agreement on a comprehensive definition of trust (Hosmer, 1995), key elements of trust that can be abstracted from the organizational and management literature could boil down to these three: *reliance* (Rotter, 1980), *risk* (Sheppard & Sherman, 1998; Rousseau, Sitkin, Burt, & Camerar, 1998; Mayer, Davis, & Schoorman, 1995), and, *benevolence* (Wicks, et al, 1999). It is also theorized that these three elements of trust are fundamentally and simultaneously correlated to three critical components of high-performing project teams: an economical, *transactional* approach equating to the need for ‘reliance’ on collaborative performance; a dynamic, *uncertain* ambience with known or unknown ‘risk’ in the rapidly changing project environment; and, a *transformational* orientation, with ‘benevolence’ transfused among the team members to enhance, empower, and thus transform each other for personal, professional, and community benefit. Concurrently, when trust is infused with the three components of reliance, risk, and benevolence, it is proposed that this ubiquitous construct becomes the irreducible imperative informed by the five components of Emotional Intelligence (Goleman, 2006).

### 2.1 Emotional Intelligence and Trust

Emotional Intelligence (or EQ) has gained increasing attention in the literature as it is strongly allied to relationship-building and successful outcomes (Goleman, 1995). There are five broad aspects to emotional intelligence: self-awareness, self-regulation, motivation, empathy, and social skills that work together in varying degrees to build enduring trust. *Self-awareness* enables the understanding of one’s own strengths and weaknesses; *self-regulation* involves the control of one’s emotions; *motivation* seeks excellence in goal-seeking; *empathy* connotes a deep understanding and development of others; and, *social skills* are fostered by sensitive communication and tactful change management. These traits are pragmatically deployed through cultivating strong relationships, motivating and developing people, enhancing self-development, and disseminating goodwill. Thus, emotionally intelligent people are described as those who have cultivated four broad characteristics (Goleman, 2006): (1) They are good at *understanding* their own emotions (self-awareness); (2) They are good at *managing* their emotions (self-management); (3) They are *empathetic* to the emotional drives of other people (social awareness); and, (4) They are good at *handling* other people’s emotions

(social skills). Emotional intelligence hinges on the ability to deploy emotions in constructive, creative, and perceptive ways to build solid relationships resulting in high levels of trust. The contextual, environmental, and systemic causes and management of emotions in the ecosystem of the fast-paced project environment must be understood intelligently by emotionally competent project team leaders and team members.

It can be surmised therefore that Emotional Intelligence (EQ) is indeed the cornerstone of trust. Consequently, a valuable necessity and outcome of successful project leadership (which *requires* emotional intelligence) is trust. Preliminary research indicates that EQ and trust are related to each other; and this has been demonstrated in educational settings, in corporate and manufacturing arenas, and in local public health environments (Knight, Bush, Mase, Riddell, Liu, & Holsinger, 2015). Fambrough & Hart (2008) found that leaders need to consider the significance of emotions in their organizations. Thus, Emotional Intelligence (EQ), coupled with healthy relationships between the project leader and the team members, strengthen overall leadership effectiveness.

In recent research, unsuccessful leaders attributed their failure 11 percent of the time to technical incompetence and 23 percent of the time to lack of Emotional Intelligence (Boyatzis, 2004). Low emotional intelligence can be deleterious to effective project leadership and teamwork: it is related to poor interpersonal relationships, ineffective project change management, and low team morale—all of which can have a negative impact on both project team leaders and team members.

## *2.2 Trust and Distrust*

Trust is clearly a positive trait to be sought and earned. It has emerged as a fundamental intangible for successful societal connections in the intricate and interdependent world we live in today. Therefore, the importance of trust in the socially relevant context of a fast-paced and complex project environment with a diversity of stakeholders and team members can well be imagined. On the obverse, the deleterious consequences of distrust or betrayal of trust are all too evident in the contemporary world of politics, economics, and business—with consequent damage to relationships, roles, reputations, and productivity. Indeed, distrust has engendered weakened relationships, low productivity, and conflictual situations. Behavioral perspectives of trust thus contribute to a recognized dichotomy between trust and distrust in relationships (Sitkin & Roth, 1993). Whereas trust is regarded as good and viewed positively, distrust is viewed negatively, and considered as bad (Lewicki, McAllister, & Bies, 1998). Consequently, the trust versus distrust dilemma constantly confronts us as we face new situations, new people, new adversities, and even new successes (Barnes, 1981).

The Webster Dictionary defines distrust as “the lack or absence of trust”. In sociology, Ross, Mirowski, & Pribesh define distrust/mistrust as the “absence of faith in other people” (2001:568). However, Lewicki, et al (1998) examined the organizational literature and have argued that trust and distrust are separate dimensions—and not opposites on a continuum as intuitively believed. Their rationale for this approach to the trust-distrust debate is to point out that “relationships are multifaceted or multiplex” (1998:442), and that we therefore need to allow both trust and distrust to co-exist. McKnight & Chervany (2001-2002) have summarized

the literature on definitions of trust and distrust and their respective conceptual models—along with antecedent and contextual variables for each construct. Thus, Luhmann (1979) argues that distrust is in fact a “functional equivalent of trust”, rather than its opposite (1979:71).

### *2.3 Social Exchange Theory and Trust*

The Social Exchange Theory (Emerson, 1976) combines sociology, psychology, and economics to determine risks and benefits through a cost-benefit analysis. According to the Social Exchange Theory, we seek factors in social contexts (as exemplified by teamwork) that influence our decisions to pursue, sustain, or terminate relationships. In these relationships, people are motivated to attain some reward by sacrificing something of value—which in turn is construed as a cost of the relationship (Redmond, 2015). Thus, in exercising trust in a socio-economic context, some personal cost—intangible or tangible—is involved in the inherent social exchange. Ideally, the rewards of the relationship should equal or exceed the costs, the exchange being social behaviour that may result in both economic and social outcomes of value.

In a cross-cultural study across four countries comparing strangers as well as neighbors, it was found that social distance was inversely proportional to cooperation; and cooperation in turn was linked to social identity and the propensity toward trusting relationships between people (Buchanan, Croson, & Dawes, 2002). According to Stafford (2008), social exchanges are predicated on interpersonal relationships and involve trust, rather than legalities and commercial bargaining. Thus, the social exchange process brings satisfaction when people receive fair returns for their efforts and expenditures. In general, mutual trust is generally perceived as the social capital of a reciprocally beneficial relationship (Möllering, Buchmann & Lee, 2004).

### *2.4 Leader-Member Exchange Theory (LMX) and Trust*

The LMX theory (Graen & Uhl-Bien, 1995), according to which leaders form different kinds of relationships with various groups of subordinates, has received extensive empirical support. One group, referred to as the ‘in-group’—the core project team members—is favoured by the leader. Members of the core group (in-group) generally have stronger relationships with the leader and have more access to the organizational resources. By contrast, other, peripheral project team members are viewed as the ‘out-group’ experiencing weaker relationships with the project leader, and consequently attracting fewer valued resources from their leader.

The LMX theory views team leadership as consisting of several dyadic relationships linking the leader with individual followers. Parties to the LMX relationship evaluate each other’s integrity, beneficence, and competence through personal interaction. Persistence in these positive traits increases trust. In a project environment, trust becomes especially valuable in the team leader’s relationships with the core group members who stay with the project throughout the project life cycle. Research indicates that the quality of these relationships is seen to be positively related to calculative exchanges, and the trust thus engendered appears to be vulnerable even in high-quality LMX relations (Scandura & Pelligreni, 2008). This means

that these relationships in the fast-paced environment of a mega-project can be transactional, rather than be deeply affective.

Trust has become a poignant element in the Leader-Exchange Theory (LMX), as the team members look up to the project manager to be both trusting of them, and trustworthy as the leader. Within each project team, trust can be accelerated by transparent communication, cooperation, and collaboration. Trust-building in high-performing teams necessitates the Emotional Intelligence (EQ) components of self-awareness, self-regulation, motivation, empathy, and social skills. Therefore, the imperative role of trust in collaborative relations in high-performing, goal-oriented project teams has become increasingly evident (Nielsen, 2004).

It has been found that the LMX Theory is applicable for a deeper understanding of trust and trustworthiness in dynamic team environments (Jawahar, Stone, & Kluemper, 2017). The quality of the LMX relationship is reflected in the degree of integrity, support, respect, and obligation evidenced. Thus, a high LMX relationship is characterized by mutual trust, loyalty, and positive behaviours that extend outside the employment contract; whereas, a low LMX relationship is one that stays within the bounds of the employment contract such that the employee performs his or her job, but does not go ‘above and beyond’ task requirements (Brower, Schoorman, & Tan, 2000).

The LMX Theory focuses our attention on the significance of communication in leadership and teamwork. Constructive and transparent communication enables project managers and project team members to develop, grow, and maintain beneficial exchanges. When this communication is accompanied by beneficent features such as mutual trust, respect, and devotion, it reinforces effective project leadership and teamwork as imperative to project success.

### **3. The Triangle of Trust: Beneficence, Reliance, and Risk**

A widely accepted definition of trust is: “...the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor—irrespective of the ability to monitor or control that other party.” (Mayer, Davis, & Schoorman, 1995:712).

In a Special Issue on *Trust in Organizations* [Academy of Management Review, vol. 23, 1998], it was determined that the most common description of trust was that proposed by Mayer, Davis, & Schoorman (1995), where trust was defined as the *willingness to be vulnerable*. Simply having a willingness to be vulnerable, however, does not require an individual to take on any risk. Risk can be considered a counterpart of trust, and in some ways an essential harbinger of trust. It can be argued that without an element of risk, there is little need for trust: when trust is risk-free, at least in theory, anyone can be trusted. On the other hand, when risk is excessive, trust could be problematic. However, trust need not be equated with the absence of risk. In fact, an optimal evaluation of risk can be a basis for the exercise of trust. In this context, a common theme among models of trust is vulnerability, where the trustor willingly assumes risk by delegating responsibility to the trustee; the level of trust, and the

willingness to trust, are indicative of the amount of risk that one is willing to take (Schoorman, Mayer, & Davis, 1996, 2007).

Several key adjectives have been used to describe the components of trust in the literature: these include integrity, empowerment, reliance, loyalty, ability, beneficence, risk, competence, ethics, and respect. Of these, three attributes have been abstracted in this paper to encompass the essence of trust in high-performing project teams: Risk, Reliance, and, Beneficence. When trust is infused with these three components, it becomes the irreducible imperative for project success. It can be seen that the triangulation of reliance, risk, and benevolence in trust can be traced back to the five aspects of Emotional Intelligence: *self-awareness* is needed to become a reliable person who can be trusted; *self-management* provides the emotional control that enhances trust; *social awareness* enables one to calibrate levels of trust towards individual team members; and, *social skills* are required to enhance the perception of trustworthiness in an interpersonal context (Goleman, 2006; Salovey & Mayer, 1990).

Beneficence is related to the Leader-Member Exchange (LMX) Theory, as the dyadic relationship between the project leader and individual team members is fostered significantly through such *beneficent* traits as kindness, empathy, and understanding that deepen the trust between the project leader and each team member in the vertical relationship. Similarly, the Social Exchange Theory that fosters strong peer interactions and exchanges of social and economic ties encourage *reliance*: this is because project success through the high-performing project team is predicated on the substantial reliability of each team member. Finally, the known and unknown risks inherent to the dynamic project environment, laced with tapered uncertainty, calls for trust as a paradoxical but necessary response. Without trust among team members, and between the team leader and team members, it is virtually impossible to nurture a high-performing project team. The three elements of the Triangle of Trust—beneficence, reliance, and risk—are explicated further below.

### 3.1 Beneficence

Beneficence is the state or quality of being kind, charitable, or beneficial to others. It is seen as the desire to want to do good for the trusting party, aside from a possible motive for reciprocation of benefits. Generalized trust is typically defined by researchers as a default expectation of people's goodwill in that they are expected to have benign intentions (Yamagishi, Cook, & Watabe, 1998). Beneficence is thus defined as an act of charity and kindness with a strong connotation of benefiting others, including extending moral obligations to them. All professionals have the foundational moral imperative of doing what is right; and, an integral part of work as a project professional is the foundational ethic of beneficence. Therefore, in high-performing project teams, the emotive trait of beneficence is vital to cement bonds among team members that result in significant understanding, goodwill, morale, and productivity toward project success.

### 3.2 Reliance

An important element of trust is rooted in the integrity of the person trusted. It is the expectancy that the work, promise, or written statement of an individual or group can be relied

upon (Rotter, 1980). According to Griffin (1967), trust is the reliance upon the behaviour of a person to achieve a desired but uncertain objective, often in a risky situation. Thus, trust connotes reliance on received information, or on a person. This also means consistency of behaviour through credible accomplishment of promises, events, incidents, and resolutions. Reliance is closely allied to the ideas of proven capability (Blois, 1999), as can be expected of competent members of a high-performing project team. There are reasonable expectations from goal-oriented project team members (Steyn, 1997) toward positive outcomes that result in project success (Anderson & Narus, 1990). Rempel, Holmes, & Zanna (1985) determined that for trust to develop, interpersonal relationships between project team leaders and team members need to be fostered, based on the mutual degree of reliability, confidence, and security. Without a high degree of reliability of project team members, it is virtually impossible to function as a high-performing project team.

### *3.3 Risk*

Trust intervenes where risk is present. Risk is integral to the behavioural demonstration of trust (Lyons & Stokes, 2012), and is a characteristic of decisions defined as “the extent to which there is uncertainty about whether potentially significant and/or disappointing outcomes of decisions will be realized” (Sitkin & Pablo, 1992:10). Mayer, Davis, & Schoorman (1995) argued that risk is an essential component of trust, where trust was characterized as a willingness to be vulnerable to another party. When the risk in a situation is greater than the trust (thus, the willingness to take the risk), the difference between them can be bridged by lowering the perceived risk to a level that can be constructively managed by trust (Schoorman, Mayer, & Davis, 2007).

Clearly, trust is a multi-faceted component of high-performing project teams, and the level of trust is related to the level of perceived risk. Greater trust is required when the risk is higher. The characteristics of both the trustee and trustor are important for trust to exist. Team leaders who act in a respectful and trusting manner through honesty, fairness, and encouragement of teamwork, help to decrease stress and increase work performance (Rego & Cunha, 2008). Trust has been shown to increase transparency, honesty, and openness related to information including admitting mistakes in order to create organizations that continue to remain viable (O’Toole & Bennis, 2009).

## **4. Optimality of Trust**

Optimality is founded upon Aristotle’s ‘golden mean’ principle for human excellence that cautions against extremes (Aristotle, 1996). The pragmatic-philosophical underpinnings of trust are yet unexplored areas of research (Wicks, Berman, & Jones, 1999), that this paper has sought to explore. Thus, optimal trust within a team can be categorized as high, medium, or low, depending on factors such as team leadership, ethnic mixture, size, and mandate. The high-performing team is characterized by interdependence among the members with “dense, reciprocal ties” (Powell, 1987). This is ‘high trust’ based on high interdependence. In a nutshell, both the philosophical and practical boundaries of trust need to be considered for it to be optimally effective in a dynamic project team setting. Therefore, trust levels should be contextualized, and may fall anywhere on the spectrum between minimal trust to high trust,

depending on the person and situation: this means knowing whom to trust, how much to trust, and with respect to what matters (Wicks, et al, 1999).

According to Wicks, et al (1999), determining the level of trust exercised by an organization is a matter of strategic choice: too much trust could be a waste of resources, whereas too little trust could be a loss of opportunity. There is also a high degree of multidirectional interdependence in relationships based on trust, as is the case for high-performing team members in a dynamic major project environment. In determining the optimality of trust, Wicks, et al (1999) outline three levels of trust: (1) High trust based on high integrity, beneficence, and high interdependence with stakeholders to minimize transaction costs for the long term, rather than depend on short-term incentives; (2) Moderate trust requiring sufficient interdependence, beneficence, and integrity to limit transaction costs with stakeholders in the medium term; and, (3) Low trust involving rational, prediction-based involvement with stakeholders to limit opportunism in the short-term.

### **5. Trust and the High-Performing Project Team**

The goal of project teamwork is to maximize the synergy among different parts of the project organization. Teams cannot perform without strong social interaction (Decker, 2015; Erdem & Ozen 2003). Of course, trust is constructed through social interaction. Research indicates that when building high-performing teams, one of the essential requirements is trust (Hakanen & Soudunsaari, 2012). It is not surprising that trust is widely recognized as an immediate and necessary antecedent to cooperative teamwork (Kramer & Tyler, 1996; Smith, Carroll, & Ashford, 1995; Blau, 1964; Deutsch, 1958). Indeed, teams whose cohesion is based primarily on mutual trust are capable of extraordinary feats beyond their own expectations (Adler, 2004; Bass, 1985).

It is to be noted though, that trust can be costly as people become “increasingly unwilling to take risks, demand greater protection against the possibility of betrayal, and insist on costly sanctioning mechanisms to defend their interests” (Tyler & Kramer, 1996:34). The demoralization effect of this on a dynamic, goal-driven, and potentially high-performing project team can be imagined. At the other extreme, complete trust may be unwise, as there is growing concern about violation or abuse of trust in organizations (Giacalone & Greenberg, 1997; Lewicki & Bunker, 1996; Robinson & Bennett, 1995; Morris & Moberg, 1994). We thus build on the idea of ‘optimal trust’ as theorized by Wicks, et al (1999), and examine its applicability to high-performing project teams as goal-oriented, risk-prone, and innovative temporary organisations. This also invokes the Aristotelean dictum of optimality by cautioning against extremes to seek a golden mean (Aristotle, 1996).

As the project team is a temporary organization composed of unfamiliar actors (Bigley & Pearce, 1998) assembled for a short period, implicit trust is unrealistic. Yet, when trust and interdependence levels are consciously and conscionably matched, trust is optimal as it creates flexibility, commitment, durability, creativity, and strong social ties (Fukuyama, 1995; Wicks, et al, 1999). In this context, continuously building trust between individuals of different cultures in a multi-functional, multi-ethnic mega-project team is an *irreducible imperative* towards optimality.



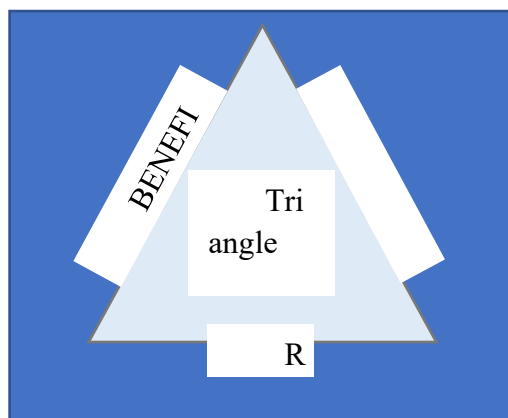
In general, as a relationship develops, trust thickens (Gambetta, 1988). Essentially, multi-ethnic teams face several intrinsic challenges: the swift trust needed to function in temporary settings (Meyerson, Weick, & Kramer, 1996); trusting in an uncertain environment (Madhok, 1995); trusting unfamiliar actors (Bigley & Pearce, 1998); trusting multi-ethnic participants with variable levels of trustworthiness (Barney & Hansen, 1994); and, trusting in individuals different from themselves (Bigley & Pearce, 1998). Trust enables delegation, transparent communication, feedback mechanisms, as well as morale and team spirit. This enables the project leader to lead effectively, and to focus on project priorities, goal setting, and ultimately, project success. Further, the ability of project team members to be effective, reliable, and consistent helps in building a high-performance project team that enables the project manager to achieve the project goals. This ultimately leads to higher, overall team satisfaction.

Trust also enhances the project organization's ability to adapt to complexity and change (McAllister, 1995)—two characteristics that describe a dynamic project environment. Early in a team's existence, a team member's trusting beliefs have a direct, positive effect on his or her trust in the team, and perceptions of team cohesiveness (Jarvenpaa, Shaw, & Staples, 2004). Thus, trust seems to be important for both effective performance and high team satisfaction (Barnes, 1981).

## 6. The Triangle of Trust

The Triangle of Trust depicted below and introduced in this paper interlocks *Beneficence*, *Reliance*, and *Risk*. Though there are several attributes constituting trust and trustworthiness, these three elements capture the essentials of trust for a high-performing project team to achieve project success. This is made possible by inculcating strong relationships through genuine care and empathy enshrined in *beneficence*; the need for competent project team members to evidence high *reliance* on each other and having a reputation for reliability themselves; and, the inevitability of *risk* in a project environment that needs to be proactively tackled through high levels of trust.

The Triangle of Trust for High-Performing Project Teams



## **7. Trust and Project Success**

The LMX Theory has demonstrated that trust plays a central role in relationships between the project leader and team members, and thus influences desired outcomes such as satisfaction, commitment, and performance (Costigan, Insinga, Berman, Ilter, Kranas, & Kureshov, 2006; Dirks, 1999). The importance of trust in leaders through history may be universally applied. Ratings from 60 societies/cultures reveal that trustworthy leaders are perceived around the globe to be more effective (Den Hartog, et al, 1999). In a meta-analysis of the literature devoted to trust and leadership, it was found that trust is related to job satisfaction and performance, goal attainment, organizational commitment, satisfaction with the leader, and constructive and affective leader-member exchange (Dirks & Ferrin, 2002).

The Triangle of Trust comprising beneficence, reliance, and risk form the dynamic bedrock of trust-building in high-performing project teams. Armed with this mind-set and practice, high-performing project teams should gravitate towards project success, aided by the amalgamation of peers as underscored by the Social Exchange Theory. The soft skills of Emotional Intelligence (EQ) inherent in trust and trustworthiness are critical to achieving successful project outcomes, in addition to high levels of technical competence. In this context, the cooperation, collaboration, and communication levels between project leaders on the one hand, and team members on the other, are of paramount importance in terms of the Leader-Member Exchange (LMX). Indeed, the optimal trust displayed under varying conditions prevailing in a fast-paced project environment should provide the flexibility to incorporate the risks and changes inherent in the project life cycle.

## **8. Summary and Conclusions**

For centuries, lack of trust has been the biggest impediment to cross-cultural enterprise. Yet, there is growing need to understand how trust and culture interact (Doney, Cannon, & Mullen, 1998). With globalization and increasing diversity of the workforce, trust may be a fundamental factor in enabling mutual attraction and willingness to work together across national boundaries (Berscheid & Walster, 1978; Newcomb, 1956). Trust is more difficult in situations of diversity because people are uncertain about the culture-based behaviour of others (Kipnis, 1996). On the other hand, the exercise of trust can be viewed as a lubricant (Arrow, 1974), a cohesive factor (Baier, 1986), and as a veritable simplifier of complex transactions (Powell, 1996). As constructive work is being accomplished through multi-disciplinary, self-directed project teams, lack of trust can truly be a barrier to communication and productivity, especially across multiple disciplines and cultures.

Trust is a broad construct that includes the reciprocity associated with leader-member exchange (LMX) while also incorporating perceptions of trustworthiness, reliability, benevolence, openness, receptiveness, and the emotions associated with trust (Brower, Schoorman, & Tan, 2000; Butler 1991; McAllister 1995). Moreover, trust inherently requires risk-taking (Mayer, et al. 1995). Despite some anomalies, LMX and trust have been shown to have common features (Brower et al, 2000). They both develop over time through reciprocal, mutually reinforcing influence between the project leader and team members. Ability, competence, and performance are positively related to LMX quality and trustworthiness in

organizations (Dirks, 1999; Mayer, Davis, & Schoorman, 1995; McAllister 1995). Despite the reciprocity inherent in the LMX theory, trust may not result in mutual benefit, though it may be expected or implied. High member performance early in the relationship leads to greater trust and higher quality leader-member exchange, which lead to greater support provided by the leader. This increases member performance (Graen & Scandura 1987). Hence, LMX and trust are reciprocally related and mutually reinforce each other over time.

Whereas the Leader-Member Exchange (LMX) describes the vertical relationship between the project team leader and the team members, the Social Exchange Theory captures the essence of horizontal, trusting relationships among peers in a high-performing project team. In this context, the Emotional Intelligence (EQ) factors of self-awareness, self-regulation, motivation, empathy, and social skills are essential to fostering trust and trustworthiness. In reviewing the array of attributes that contribute to the concept of trust, three elements have been identified to capture the pithy kernel of trust in high-performing project teams: beneficence, reliance, and risk. All three of these factors interplay to optimally foster trust through the changes and challenges of a dynamic mega-project steered by the high-performing project team toward successful project outcomes.

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# Appraising Quantity Surveying Students' Academic Performance: A Case of Kaduna State University, Nigeria

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## Abstract:

Quantity Surveyors (Qs) are professionals within the Architectural, Engineering and Construction (AEC) industry whose services are global and cuts across cost management, procurement and contractual issues. The performance of students in Nigerian tertiary institutions especially those within the Built Environment has been a major concern to all stakeholders. However, researches in this area within the Nigerian Construction Industry are scarce. The study appraised Quantity Surveying students' performance at Kaduna State University, Nigeria in an attempt to understand the root cause of decline in performance. A questionnaire survey was developed and administered to 169 students in 200-500 levels of study. The questionnaires were 100% completed with 168 usable for analysis. Data were analyzed using descriptive statistical tools like percentage, frequency, and mean score. The relationships between variables were analyzed with Statistical Package for Social Sciences (SPSS) specifically the Kendall Tau-B and the Point-Biserial Correlations, to ascertain the relationship between student's level of study, their gender and age. Parent's economic status, student's source of livelihood and student's engagement in extra stream of income were also analyzed to ascertain their influence on students' performance. Findings indicate that the students' performance is on the decline as indicated in their Cumulative Grade Point Average (CGPA). The study also revealed that parents' economic status, students' source of livelihood and engagement in extra stream of income while studying had no impact on students' academic performance.

*Keywords:* built environment; quantity surveying; quantity surveyors; performance; stakeholders

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## 1. Introduction

Students are potential assets to every nation, as they become the source of a nation's workforce after graduation thereby developing the economy of any nation. Hence, their performance in tertiary institutions is a source of concern to stakeholders within and outside academics (Moktar *et al.*, 2012). Their performance is also a determinant factor in evaluating a tertiary institution's or a country's quality of education as well as the quality of graduates produced (Fajar *et al.*, 2019; Coetzee, 2011).

Studies on students' performance have received attention in recent times globally. There exist several studies on the performance of students in courses of study such as Accounting, Pharmacy, Medicine, Mathematics and many more. There are also several studies on country basis about students' performance. However, limited abounds on students' performance in Built Environment Courses such as Quantity Surveying (QS). In addition, studies on students' performance in tertiary institutions of Nigeria are limited and open for exploration. Paul and

Jatau (2018) in their study reported a continuous decline in students' academic performance especially those in Built Environment related courses in tertiary institutions of Nigeria. Quantity Surveyors (Qs) are professionals with pivotal roles within the Architectural, Engineering and Construction (AEC) industry whose services are global and cuts across cost management, procurement and contractual issues (Olanrewaju and Anahve, 2015). In Nigeria, students are required to spend a minimum of five years in the university with a minimum of 1.50 CGPA (pass degree) before they graduate and then pass the professional exams before they qualify to practice as Qs. The specific roles that Qs play within the construction industry make the performance of Quantity Surveying students important.

Although measuring students' performance is complex, the cumulative grade point average (CGPA) is a common measure used by tertiary institutions in admitting students for postgraduate studies, recruiting new teachers, financial aid and other recognition. It is very relevant in accessing jobs as well (Al-Tamimi and Al-Shayeb, 2002). In Nigeria, it is also the major indicator of students' performance.

The aim of this study is to appraise the academic performance of Quantity Surveying students of Kaduna State University, Nigeria in an attempt to understand the root cause of decline in students' performance. The study appraised the impact of students' level or year of study, gender, age, parents' economic status, student's source of livelihood, and engagement in any extra stream of income on student's performance.

### *1.1 Factors affecting students' performance*

Several studies explored the concept of factors affecting students' performance. There have been divergent views about the determinant of academic performance as some educators point at entry standards while others are of the opinion that non-academic factors should be considered as further determinants of academic performance (Olatunji *et al.*, 2016). Hijazi and Naqvi (2006) posited that students' performance is dependent on three broad factors: socio-economic, psychological and environmental factors. They outlined other factors affecting students' performance to include learning abilities, race, gender and time allocated for study. While Harb and El-Shaarawi (2006) in their study reported competence in English, class participation, missing lectures and study hours achieved as factors affecting students' performance. They also stressed that hard work, previous schooling, parent's education, family income and self-motivation significantly affects students' performance.

Norhidayah *et al* (2009) assessed demographic (parents' education and income), active learning, students' attendance, involvement in extracurricular activities, peer influence and course assessment as factors affecting students' performance. In a research conducted by Maina *et al* (2017), they reported that students' performance is affected by several factors including environmental, social, economic, cultural status, school background, lecturer characteristics, school facilities and resources, students' attitude and discipline. While Mustaq and Khan (2012) identified factors affecting students' performance to include communication, learning facilities, proper guidance and family stress. Guleker and Keci (2014) and Chen and Lin (2006) reported the effect of lecture attendance on students' performance. While Nzewi *et al* (2012) and Faisal *et al* (2014) reported that time management plays a major role in how students performed.

However, Nzewi et al (2012) reported that other intervening factors such as health, biological, psychological and non-residency of students are greater factors affecting students' performance.

Olatunji et al (2015) studied seven factors affecting students' performance. The first is students' background including parents' level of income, lack of parental care and family roles while the second factor is students' behavior, which bothers on lack of concentration. The third factor is school administration, which includes lack of competent and effective lecturers, unavailability of instructional materials for practical teaching and lack of basic education facilities. The fourth is regulatory and supervisory issues, which includes inadequate supervision by regulatory authorities. The fifth factor is teaching style that includes the way lecturers speak and the sixth is English language and communication competence; while the seventh is the assessment methods adopted. While Shahzadi and Ahmad (2011) in their study reported that students' academic performance depends on factors such as learning skills, home environment, academic interactions and study habits. Other variables that have an influence on a student's ability to achieve academically, including non-cognitive factors such as, motivation, the lecturers, family circumstances, background, previous academic performances, study skills, and many more. In addition to the aforementioned, there are cognitive factors, such as IQ and standardized test scores, which have traditionally been associated with academic achievement (Coetzee, 2011).

In their study, Junio and Liwag (2016) identified factors affecting students' performance to include socio-economic status, students' aptitude, learning facilities and teachers' characteristics. Another factor reported to play a major role in students' performance is gender (Ahmad *et al.*, 2015; Jayanthi *et al.*, 2014). Jayanthi *et al* (2014) also identified other factors influencing students' performance to include nationality of student and students' engagement in extracurricular activities. Paul and Jatau (2018) and Jayanthi *et al* (2014) identified students' interest in their course of study to affect their academic performance. In a study conducted by Fajar *et al* (2019), they broadly classified factors affecting students' performance to include teacher factor, student factor, home factor and school factors.

### *1.2 Relationship between identified factors and students' performance*

Findings from existing studies indicate that the identified factors affect students' performance either positively or negatively while some had no influence. Past studies have identified study habit, student's self-concept, teacher's qualification, teaching method, school environment and government as factors influencing students' academic performance (Olatunji *et al.*, 2016). In their research on Pakistani students, Hijazi and Naqvi (2006) found that mother's age and family income had no impact on students' performance while mother's education had. They concluded that an educated mother help their children improve their performance and keep track of their activities. Mustaq and Khan (2012) from their study also reported that communication, learning facilities and proper guidance had a positive impact on students' performance while family stress had negative impact on students' performance. While Guleker and Keci (2014) and Chen and Lin (2006) both reported that lecture attendance affects students' performance. Chen and Lin (2006) further reported that students who attended

lectures improved in their exam performance. Nasrullah and Khan (2015) also reported that time management not only affect students' performance but also their daily routines and activities, stress level and personal achievements.

Norhidayah *et al* (2009) reported that students whose are highly educated and had high income, actively engage in learning process, attend class regularly, engaged in extracurricular activities had higher CGPA and performed better. While students perception of frequent course assessment negatively affected their performance. Ahmad *et al* (2015) reported that female students performed better than their male counterparts did. In their study, Paul and Jatau (2018) found that students that find a course of study interesting performed better than those who did not. While Paul and Jatau (2018) and Hijazi and Naqvi (2006) both found that time allocated for study had no effect on student's performance probably due to intelligence level, intellect, memory, memory, method of teaching and personal characteristics of a student. Astin (1993) in Maruzzella (2017) reported a negative relationship between academic performance and working, either on a full-time or part-time basis. His argument is that working hours decreases the students' involvement in campus activities.

In their research, Shahzadi and Ahmad (2011) in their study found that the home environment ranked highest among the factor affecting student's academic performance at the university level.

## **2. Materials and Methods**

A descriptive cross sectional survey was used in carrying out this study. The study population was students of the Department of Quantity Surveying, Kaduna State University, Nigeria. Quantity Surveying is a five years course of study at Kaduna State University. Hence, Participants were students of 200 to 500 levels of study (or year 2 to year 5) who have written at least one semester examination with results approved by the school management and pasted in the department's notice board.

The sampling technique for this study was the purposive sampling technique to access the needed data for the study.

The data collection tool adopted for this study was a structured questionnaire comprising several sections. 169 students of 200 to 500 levels of study at the department of Quantity Surveying were administered the questionnaire developed.

Data analysis was with the statistical package for social sciences (SPSS) version 21 using descriptive statistical tools like percentage, frequency, and mean score. The Kendall Taub-B and the Point-Biserial Correlations ascertained the relationship between student's level of study, gender, age, and parents' economic status, student's source of livelihood and student's engagement in extra stream of income and their influence on students' performance.

### 3. Results and Discussion

#### *Respondents' rate of response*

169 questionnaires were self-administered to students of 200 - 500 levels of study and 169 questionnaires were retrieved as shown in Table. However, 1 questionnaire was invalid and could not be used for analysis.

Table 1: Rate of Response

Description	Number	Percentage
Number of questionnaires distributed	169	100%
Number of questionnaires retrieved	169	100%
Invalid questionnaires	1	1%
Total valid response rate	168	99%

#### *Students' CGPA*

The result shows that only 13% of students are within the second class upper range as shown in Table 2..

Table 2: Students' CGPA

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1.00	3	1.8	1.8	1.8
	1.00-2.49	70	41.7	41.7	43.5
	2.50-3.49	74	44.0	44.0	87.5
	3.50-4.49	21	12.5	12.5	100.0
	Total	168	100.0	100.0	

#### *Students' level of study*

Majority of students (51%) were in year 2 when this study was conducted as shown in Table 3.

Table 3: Students' Level of Study

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	200 Level	85	50.6	50.6	50.6
	300 Level	39	23.2	23.2	73.8
	400 Level	20	11.9	11.9	85.7
	500 Level	24	14.3	14.3	100.0
	Total	168	100.0	100.0	

#### *Students' gender*

81% of students in the department of Quantity Surveying are male while only 19% are female students as shown in Table 4.

Table 4: Students' Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	136	81.0	81.0	81.0
	Female	32	19.0	19.0	100.0
	Total	168	100.0	100.0	

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*Students' age*

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Majority of students representing 64% of respondents are within the age bracket of 21-25 years as shown in Table 5.

Table 5: Students' age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	15-20 Years	36	21.4	21.4	21.4
	21-25 Years	107	63.7	63.7	85.1
	26-30 Years	22	13.1	13.1	98.2
	30 years and above	3	1.8	1.8	100.0
	Total	168	100.0	100.0	

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*Parents' economic status*

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Majority of students representing 65% are from the middle class as shown in Table 6.

Table 6: Parents' Economic Status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Upper Class	23	13.7	13.7	13.7
	Middle Class	109	64.9	64.9	78.6
	Lower Class	36	21.4	21.4	100.0
	Total	168	100.0	100.0	

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*Students' source of livelihood*

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Majority of students representing 77% get their upkeep from their parents as shown in Table 7.

Table 7: Student's source of livelihood

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Parents	130	77.4	77.4	77.4
	Relations	23	13.7	13.7	91.1
	Friends	3	1.8	1.8	92.9
	Self	12	7.1	7.1	100.0
	Total	168	100.0	100.0	

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*Students engaged in extra stream of income while studying*

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Majority of students representing 76% do not work or engage in any extra stream of income while studying but 24% do as shown in Table 8.

Table 8: Students Engaged in Extra Stream of Income while studying

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	41	24.4	24.4	24.4
	No	127	75.6	75.6	100.0
	Total	168	100.0	100.0	

The relationship between students' CGPA and level of study was analyzed using Kendall Tau-B correlation. The result in Table 9 shows that a p-value of 0.01 is lower than the level of significance making the result significant. A correlation coefficient of 0.234 indicates there is a weak, positive relationship between student's CGPA and level of study.

Table 9: Correlations - Students' CGPA and Level of Study

			Student's CGPA	Student's Level
Kendall's tau_b	Students' CGPA	Correlation Coefficient	1.000	.234**
		Sig. (2-tailed)	.	.001
		N	168	168
	Students' Level of Study	Correlation Coefficient	.234**	1.000
		Sig. (2-tailed)	.001	.
		N	168	168

\*\* . Correlation is significant at the 0.01 level (2-tailed).

The relationship between students' CGPA and students' gender was analyzed using Point Biserial correlation. The result in Table 10 shows that a p-value of 0.01 is lower than the level of significance making the result significant. A correlation coefficient of 0.896 indicates there is a strong, positive relationship between student's CGPA and gender.

Table 10: Correlations - Students' CGPA and Gender

			Student's CGPA	Student's Gender
Students' CGPA		Pearson Correlation	1	.010
		Sig. (2-tailed)		.896
		N	168	168
Students' Gender		Pearson Correlation	.010	1
		Sig. (2-tailed)	.896	
		N	168	168

The relationship between students' CGPA and students' age was analyzed using Tau-B correlation. The result in Table 11 shows that a p-value of 0.01 is lower than the level of significance making the result significant. A correlation coefficient of 0.192 indicates there is a strong, positive relationship between student's CGPA and gender.

The relationship between students' CGPA and students' age was analyzed using Tau-B correlation. The result in Table 11 shows that a p-value of 0.006 is lower than the level of significance making the result significant. A correlation coefficient of 0.192 indicates there is a weak, positive relationship between student's CGPA and students' age.

Table 11: Correlations - Students' CGPA and Age

			Student's CGPA	Student's age
Kendall's tau_b	Students' CGPA	Correlation Coefficient	1.000	.192**
		Sig. (2-tailed)	.	.006
		N	168	168
	Students' Age	Correlation Coefficient	.192**	1.000
		Sig. (2-tailed)	.006	.
		N	168	168

\*\* . Correlation is significant at the 0.01 level (2-tailed).

The relationship between students' CGPA and parents' economic status was analyzed using Tau-B correlation. The result in Table 12 shows that a p-value of 0.263 is greater than the level of significance making the result not to be significant. Hence, there is no significant relationship between students' performance and parent's economic status.

Table 12: Correlations -Students' CGPA and Parents' Economic Status

			Students' CGPA	Parents' Economic Status
Kendall's tau_b	Students' CGPA	Correlation Coefficient	1.000	.079
		Sig. (2-tailed)	.	.263
		N	168	168
	Parents' Economic Status	Correlation Coefficient	.079	1.000
		Sig. (2-tailed)	.263	.
		N	168	168

The relationship between students' CGPA and students' source of livelihood was analyzed using Tau-B correlation. The result in Table 13 shows that a p-value of 0.714 is greater than the level of significance making the result not to be significant. Hence, there is no significant relationship between students' performance and source of livelihood.

Table 13: Correlations - Students' CGPA and Source of Livelihood

			Students' CGPA	Student's source of livelihood
Kendall's tau_b	Students' CGPA	Correlation Coefficient	1.000	.026
		Sig. (2-tailed)	.	.714
		N	168	168
	Students' source of livelihood	Correlation Coefficient	.026	1.000
		Sig. (2-tailed)	.714	.
		N	168	168

The relationship between students' CGPA and students' engagement in any extra stream of income was analyzed using Tau-B correlation. The result in Table 14 shows that a p-value of 0.513 is greater than the level of significance making the result not to be significant. Hence, there is no significant relationship between students' performance and parent's economic status.

Table 14: Correlations - Students' CGPA and Engagement in Extra Stream of Income while Studying

			Student's CGPA	Student engaged in extra stream of income while studying
Kendall's tau_b	Student's CGPA	Correlation Coefficient	1.000	-.048
		Sig. (2-tailed)	.	.513
		N	168	168
	Students engaged in extra stream of income while studying	Correlation Coefficient	-.048	1.000
		Sig. (2-tailed)	.513	.
		N	168	168



#### 4. Conclusion

This study appraised the academic performance of Quantity Surveying students of Kaduna State University, Nigeria. Seven factors were studied as factors affecting students' academic performance namely: level of study, gender and age, parent's economic status, student's source of livelihood and student's engagement in extra stream of income. Results indicate that students' academic performance is low as only 13% of students are within second-class upper grade. In addition, there are more males studying Quantity Surveying than females. Further findings revealed students' level of study affects performance as the higher the level, some students' performance dropped. The study also found that student's gender influences academic performance agreeing with the study conducted by Ahmad et al (2015). Students' age slightly affect performance whilst parents' economic status had no impact on students' performance agreeing with the findings of Hijazi and Naqvi (2006). The study found that students' source of livelihood had no impact on their performance. While students' engagement in extra stream of income, was found to have no impact on students' performance disagreeing with findings of Astin (1993) in Maruzzella (2017). The previous findings from this research in Paul and Jatau (2018) indicate that students' interest in a course of study is a major factor affecting students' performance agreeing with Jayanthi et al (2014).

#### Limitation of the Study

This study focused on quantity surveying students, which makes it difficult to generalize the results to all students in other departments of tertiary institutions across Nigeria. The CGPA was the only measure used for students' performance; other measures should be considered in subsequent researches.

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# **General Management and Economics in Construction**

# Drivers of Knowledge Management in Small and Medium Construction Companies in South Africa

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## Abstract:

Acquiring and retaining knowledge within an organisation by using the right management practices is important for the continued survival of any organisation. The realisation of this fact has brought about discussions on knowledge management (KM) practices among academics. However, small and medium construction organisations have been described to be falling short in the adoption of several management practices that could help the improvement of their service delivery and subsequent growth within the industry. Thus, this study set out to determine the various factors that could serve as drivers towards achieving proper KM within these construction organisations. The study adopted a quantitative approach using a questionnaire survey carried out among staff members and stakeholders in management positions of Grade 1 to 3 General Building organisations within the Johannesburg region of South Africa. Data gathered were analyzed using percentage, mean score, standard deviation, and one-sample t-test. The reliability of the research instrument was also tested using Cronbach alpha test. The result revealed that for small and medium construction organisations to adopt KM practices, the most prominent drivers needed are strategic planning, building trust among stakeholders, attracting and retaining competent talents within the company, and creating a competitive advantage that will help them grow in terms of the type of projects they handle.

**Keywords:** drivers; knowledge management; organization management; project management; small and medium companies

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## 1. Introduction

The importance of small and medium enterprises to the economic growth of every country as well as the hindrances to them achieving this important role has been observed in previous researches (Tshikhodo, 2016; Unnikrishnan *et al.*, 2015; Wentzel *et al.*, 2016; Yeboah, 2016). While SMEs are said to be the cornerstone of every country's economy especially in developing ones (Unnikrishnan *et al.*, 2015), their activities and productivity are challenged by problems such as poor project planning and ineffective management (Thwala and Mvubu, 2009). More importantly, is the aspect of proper management of knowledge acquired within the organisation. According to Arthur-Aidoo *et al.* (2016), most owners of SME's do not have good background knowledge of the industry in which they operate. They in most cases rely on their employees to fill in this knowledge gap. Unfortunately, it has been noted that stakeholders of the construction industry find it hard to share knowledge. Institutional memory is not being conveyed equally between the stakeholders of the construction industry (World Economic Forum, 2016). Engineers and other construction experts who possess the domain knowledge

within construction organisations tend to leave little or no knowledge at all behind for future projects when they eventually exit their organisations (Ribeiro, 2008).

It is important to note that stakeholders of any organisation are the originators and developers of knowledge through which a cumulative bank of knowledge that over time creates the process of the entire organisation is achieved (Civi, 2000). It is, therefore, imperative for organisations to develop a way in which they can manage this knowledge being generated. According to Nakamori (2010), through prehistoric knowledge, stakeholders of a company (SMEs inclusive) can solve challenges they are faced with at any time and can be creative to innovate and develop new ideas. Linde (2001) therefore suggested that empowering stakeholders with what they need to know and allowing them a fair opportunity to express their opinions which is usually based on experience allows for the transfer of knowledge. It can, therefore, be said that adopting proper knowledge management (KM) is crucial for the growth and survival of SMEs within the construction industry considering the competitive nature of the industry. Robinson *et al.* (2005) have earlier noted that KM helps create an enabling environment for the creation, storage and transfer of knowledge within an organisation.

Based on the above, this study assessed the drivers of KM in small and medium construction companies in South Africa with a view towards increasing the adoption of KM practices within SMEs in the construction industry and by extension improves their service delivery. Subsequent parts of this paper present the review of related literature, the methodology adopted for the study, the findings and conclusion. Based on the conclusion, recommendations were given.

## 2. Literature Review

Successful SME's are those organisations capable of using the resources available to them to develop and stand out in the market (Wee and Chua, 2013). Bakar *et al.* (2016) noted that SME's in the construction sector has been using resources available to them from past experiences, together with the knowledge they have developed and adapted over their years of existence to successfully carry out projects. According to CIDB (2015), most organisations operate based on the knowledge individuals have gained over the years. Civi (2000) further affirmed that knowledge is a resource in its self, and it which defines the modes and routes an organisation applies to their operational processes. Effectively managing this knowledge is important as this allows organisations to have an enabling environment for knowledge to create, stored and transferred (Robinson *et al.*, 2005). For this knowledge to be managed properly using diverse KM practices certain drivers must be put in place.

Abu *et al.* (2011) noted the importance of developing a positive organisational culture which will encourage stakeholders of an organisation to perform KM practices which will promote organisational growth. Similarly, Wee and Chau (2013) noted that trust between the various stakeholders of an organisation is an important element which needs to be achieved as they work in a collaborative environment and each individual needs to be focused on the goal of the organisation. Wee and Chua's (2013)'s study revealed that in most cases the owner of the SME has the bulk of organisational knowledge and they have the responsibility of distributing it within the organisation. The drive and willingness to share such knowledge

depends on the owner as their attitudes have a major influence on the outcome of the organisation (Arthur-Aidoo *et al.*, 2016; Wong, 2005) and the workforce is most likely to react towards such an attitude. Wong (2005) further elaborates on the importance of owners recognising and rewarding their employees, as this encourages a positive innovative attitude for employees.

When hiring potential candidates for an organisation, they should not be selected based on the job description alone. Candidate's understanding of the role they are to play within the organisation is also crucial. Additionally, these individuals should understand the roles of other stakeholders within the organisation to ensure that they have the capabilities of creating, innovate, and collaboratively share new knowledge with fellow stakeholders to ensure that the organisation is sustainable (Robertson and O'Malley Hammersley, 2000). Wee and Chua (2013) further elaborate that the closer employees are together, the more they interact to solve challenges that arise within the organisation. Employers/individuals at a managerial position and employees can reach a common ground where they are receptive to new innovative ideas (Lee and Wong, 2015). This is supported by stakeholders in the management position continuously auditing their level of knowledge within the organisation and finding alternative practices to help the organisation reach its goals (Lee and Wong, 2015; Wee and Chua, 2013). Although most SME's have limited knowledge of the construction industry, they should have KM processes in mind as they plan their projects to ensure the creation, storage and utilisation of knowledge are strategically implemented within the project, so it will add value within the organisation (Radzevicius, 2008). Owners of organisations need to carefully plan the objectives of the organisation and clearly ensure that everyone understands where exactly the organisation is going and what strategy is implemented to ensure that everyone all has a common goal (Wong, 2005).

Du Plessis (2008)'s study clearly states that organisations are faced with a rapid change of technological and methodological advancements. The 4<sup>th</sup> industrial revolution is currently in progress; research is constantly evolving literature and developing new ideas which can improve organisations processes. As research advances it is important that the stakeholders of the construction industry are aware of the changes, keep up with the changes and understand how to use and implement the development changes (Hughes 2014; Zolkiewski, 2018). KM can be further enhanced through creating and supplying an adequate supporting technological interface that stakeholders will find appealing and useful in enriching their current capabilities and retrieving the knowledge to carry out works in the future (Ribeiro 2009). Pöltner and Grechenig (2010) review clearly illustrate the importance of information technology (IT) as it enables organisations to create networks in which the KM processes can be carried out to overcome upcoming complexities in the construction sectors. Due to limited resources, upcoming SME's can take advantage of the freeware and basic ICT technology available to them to implement their strategic KM process which will allow for the organisation to grow and expand their performance capabilities (Brand and Huizingh 2008; Lee and Wong, 2015). At a later stage, SME's will find a need to improve their IT systems into more advanced systems which will tackle complex activities within the organisation (Brand & Huizingh 2008).

Also, most organisations send their employees for adequate up-skill training and knowledge acquisition to ensure that they are at a competitive advantage (Thwala and Phaladi, 2009; Wong, 2005), but most Grades 1-3 SME's are at a position where they lack time, financial and human resources for such initiatives to be implemented in the organisation (Wee and Chua 2013; Wong, 2005). Thus, organisations can be innovative by reviewing the processes within the organisation on a short-term basis whereby they can pinpoint potentials challenges that may arise and collaboratively deal with them immediately instead of waiting till these problems become bigger and require special training to be attended to. This allows for the stakeholders to ask a question and reduces the level of uncertainty (Lines and Reddy-Vardireddy, 2017). Such processes assist individuals to codify knowledge and know exactly what to do when something similar occurs again (Wee and Chua, 2013). Table 1 shows the assessed drivers of knowledge management based on the review of literature.

Table 1: Drivers of Knowledge management

Drivers	Authors
Resource efficiency	Bakar <i>et al.</i> (2016); Wee and Chua (2013)
Positive organizational culture	Abu <i>et al.</i> (2011)
Implement technological interface	Brand and Huizingh (2008); Lee and Wong (2015); Pöltner and Grechenig (2010); Ribeiro (2009)
Competitive advantage	Thwala and Phaladi (2009); Wong, (2005)
Strategic planning	Radzevien (2008); Wong (2005)
Attract and retain good employees	Robertson and O'Malley Hammersley (2000)
Knowing each other's stakeholders' roles	Robertson and O'Malley Hammersley (2000); Wee and Chua (2013)
Trust between stakeholders	Wee and Chau (2013)
Co-operation and partnerships	Lee and Wong, (2015); Wee and Chua (2013)
Attitude of management	Arthur-Aidoo <i>et al.</i> , 2016; Wong, 2005
Rewards and recognition	Wong (2005)
Creating efficient employee screening assessments	Robertson and O'Malley Hammersley (2000)
Creation of technologies for future	Pöltner and Grechenig (2010); Ribeiro (2009)
Educational and up-skill training programs	Thwala and Phaladi (2009); Wong, (2005)
Benchmarking	

### 3. Research Methodology

In assessing the drivers of KM in small and medium construction companies in South Africa a survey approach was adopted. The survey was conducted within the greater Johannesburg region, targeting relevant stakeholders who worked for SMEs with a CIDB grading between 1 and 3 in General Building. The respondents for the study include management and staff members of SMEs within the study area. These respondents were sampled based on their willingness to participate in the survey and by the virtue of their construction experience. Based on findings from the review of literature, a structured questionnaire was developed and was used to harness information regarding the drivers of KM with small and medium construction companies. The choice of using a questionnaire is since the questionnaire has been adjudged to be easiest and most widely used research instrument in most social researches and it has the ability to cover a wide range of respondents (Blaxter *et al.*, 2001; Tan, 2011). A total of 80 questionnaires were conveniently distributed with 53 retrieved and found fit for data analysis. The questionnaire used was designed in sections. The first section gathered information on the respondent's background, while the second section

sort answers regarding the drivers of KM in small and medium construction companies. Respondents were provided with a list of drivers identified from literature to rate based on their level of significance. A Likert scale of 1 to 5 was employed, with 5 being very high, 4 being high, 3 being average, 2 being low and 1 being very low. Data analyses were done using percentage for data on the background information of the respondents. Mean Item score (MIS), standard deviation (SD) were used to rank the identified drivers based on their rating with the highest mean value ranking first. However, where two drivers have the same mean value the one with the lowest standard deviation was ranked first as suggested by Field (2005). Furthermore, a one-sample t-test was further used to identify the level of significance attached to the identified drivers by the respondents. The reliability of the questions in this second section was also tested using Cronbach's alpha test which gave an alpha value of 0.954, thus implying high reliability of the questionnaire used.

## **4. Findings and Discussions**

### *4.1 Background information*

Data analysis of the response gotten on the background information of the respondents revealed that 2% of the respondents had no formal qualification, 9% had a Grade 9 qualification, 28% had a Grade 12, 38% had a diploma, and 23% had a bachelor's degree. The result further revealed that only 65% of these respondents have qualifications that are related to construction, with the remaining 35% being from other fields that are not construction related. Also, 21% of the respondents were the owners of the SMEs sampled, 4% were quantity surveyors within the SMEs, 30% were construction managers, and 45% were foremen/supervisors. In terms of the respondents' years of experience within the construction sector, the result revealed that 17% of respondents have between 1 to 3 years of experience, 30% have 4 to 6 years, 25% have 7 to 10 years, and 28% have 11 or more experience in the construction industry. Most (43%) of these respondents work in an organisation that is eligible to handle projects between R0 to R200,000, while 15% and 42% work within organisations that handle between R200,000 to R650,000 and R650,000 – R2million. Based on the result, it can be deduced that although the qualification level of workers within the assessed SMEs is somewhat low, their level of experience within the industry is high enough to give considerable answers to the research question base on experience.

### *4.2 Drivers of KM in Small and Medium Construction Companies*

In determining the drivers of KM in small and medium construction companies in South Africa, 15 key drivers were identified from the review of literature as seen on Table 1, and presented to the respondents to rate. One sample t-test was applied to determine the significance of each of the identified drivers. A null hypothesis which states that a driver is unimportant when the mean value is less than or equal to the population mean ( $H_0: U \leq U_0$ ) was set. The alternate hypothesis set was that a driver was important when the mean value is greater than the population mean ( $H_a: U > U_0$ ). The population mean ( $U_0$ ) was fixed at 3.0 (the mid-point for the Likert scale adopted) and the significance level set at 95%. Thus, a driver is said to be important if it has a mean value of above 3.0. Result in Table 2 shows a two-tailed p-value



which represents the significance of each identified driver. This significant p-value was further divided by two as shown in Table 3 to get the significant value for a one-tailed test about the test hypothesis (i.e.  $H_a: U > U_0$ ).

Table 2: One sample t-test statistics

Drivers	Test Value = 3.0			95% Confidence Interval of the Difference		
	t	df	Sig. (2-tailed)	MD	L	U
Attitude of management	12.868	52	0.000	1.245	1.05	1.44
Creating efficient employee screening assessments	10.889	52	0.000	1.151	0.94	1.36
Attract and retain good employees	13.822	52	0.000	1.340	1.15	1.53
Educational and up-skill training programs	10.544	52	0.000	1.226	0.99	1.46
Rewards and recognition	7.963	52	0.000	1.170	0.88	1.46
Competitive advantage	11.867	52	0.000	1.302	1.08	1.52
Resource efficiency	13.022	52	0.000	1.283	1.09	1.48
Positive organizational culture	11.243	52	0.000	1.245	1.02	1.47
Co-operation and partnerships	11.898	52	0.000	1.226	1.02	1.43
Knowing each other's stakeholders roles	6.768	52	0.000	0.887	0.62	1.15
Trust between stakeholders	12.373	52	0.000	1.434	1.20	1.67
Implement technological interface	7.856	52	0.000	0.981	0.73	1.23
Creation of technologies for future	8.961	52	0.000	1.075	0.83	1.32
Benchmarking	12.561	52	0.000	1.283	1.08	1.49
Strategic planning	20.616	52	0.000	1.604	1.45	1.76

**Note:** MD. = Mean Difference, L = Lower, U = Upper

Result in Table 3 shows the summary of the t-test conducted with the rankings of each identified drivers. Looking at the SD column of the table, all the assessed variables aside 'rewards and recognition' have an SD of below 1.0. This implies that there is little variability in the data and consistency in agreement among the respondents with respect to these fourteen drivers. However, there seems to be some variability in the rating of rewards and recognition by the respondents as an SD of 1.069 was derived. Furthermore, from the table, all the assessed drivers have a mean value of well above the 3.0 cut off point. This implies that the respondents considered all the assessed drivers to be important. Similarly, a look at the last column shows the significant p-value of each of the identified drivers shows that at 95% confidence level, all the 15 assessed drivers were considered significant, as a significant p-value of below 0.05 was derived. This result implies that if proper adoption of KM practices is to be achieved with SMEs within the South African industry, all the assessed drivers must be in place. Chief of these drivers are strategic planning ( $MIS=4.60$ ,  $sig. = 0.000$ ), building trust among stakeholders ( $MIS=4.43$ ,  $sig. = 0.000$ ), attracting and retaining competent talents within the company ( $MIS=4.34$ ,  $sig. = 0.000$ ), and creating a competitive advantage that will help them grow in terms of the type of projects they handle ( $MIS=4.30$ ,  $sig. = 0.000$ ).

Through strategic planning of activities within an organisation, more knowledge can be gained as activities unfold. Radzevien (2008) has earlier submitted that even though most SME's have limited knowledge of the construction industry, they should have KM processes in mind as they plan their projects. Similarly, the right KM practices to be adopted at every stage would have been properly planned out from the onset. This will help promote a positive organisational culture that allows the adoption of KM practices and at the same time attain

organisational growth as observed by Abu *et al.* (2011). The findings of this study are also in line with Wee and Chau (2013)'s submission that trust between the various stakeholders of an organisation is an important element in achieving organisational goals. By building trust among stakeholders or workers within SMEs, proper sharing of knowledge can be achieved. Robertson and O'Malley Hammersley (2000) have earlier noted the importance of hiring the right set of employees for any job. Findings of this study corroborate this submission as it has revealed that attracting, employing and retaining the right sets of employees for the job can go a long way in the acquiring, retaining and transferring of knowledge within SMEs. It has been observed that construction stakeholders and organisations (SMEs inclusive) need to be up-to-date with technological and innovative advancement that can help improve their service delivery (Hughes 2014; Zolkiewski, 2018) and by extension increase their knowledge bank. Through this better competitive advantage can be gained over other organisations within the industry. Thwala and Phaladi (2009) have also noted the need to gain a better competitive advantage through adequate up-skill training and knowledge acquisition for employees. The findings of this current study agree with this submission as creating a competitive advantage that will help SMEs grow in terms of the type of projects they handle is identified as one of the crucial drivers of KM within SMEs in the construction industry.

Table 3: Summary of t-test showing rankings of the drivers of KM in SMEs

Drivers	MIS	SD	SE	Rank	t	Sig. (1-tailed)
Strategic planning	4.60	0.566	0.078	1	20.616	0.000
Trust between stakeholders	4.43	0.844	0.116	2	12.373	0.000
Attract and retain good employees	4.34	0.706	0.097	3	13.822	0.000
Competitive advantage	4.30	0.799	0.110	4	11.867	0.000
Resource efficiency	4.28	0.717	0.099	5	13.022	0.000
Benchmarking	4.28	0.744	0.102	6	12.561	0.000
Attitude of management	4.25	0.705	0.097	7	12.868	0.000
Positive organizational culture	4.25	0.806	0.111	8	11.243	0.000
Co-operation and partnerships	4.23	0.750	0.103	9	11.898	0.000
Educational and up-skill training programs	4.23	0.847	0.116	10	10.544	0.000
Rewards and recognition	4.17	1.069	0.147	11	7.963	0.000
Creating efficient employee screening assessments	4.15	0.770	0.106	12	10.889	0.000
Creation of technologies for future	4.08	0.874	0.120	13	8.961	0.000
Implement technological interface	3.98	0.909	0.125	14	7.856	0.000
Knowing each other's stakeholders' roles	3.89	0.954	0.131	15	6.768	0.000

**Note:** MIS = Mean Item Score, SD = Standard deviation, SE = Standard Error

## 5. Conclusion

This study assessed the drivers of KM adoption within small and medium construction organisations in South Africa. Using a quantitative approach with data gathered from staff members and stakeholders in management positions of Grade 1 to 3 General Building organisations within the Johannesburg region of South Africa, the study has been able to reveal the key drivers of KM adoption within SMEs in the construction industry. The study concludes that for proper KM adoption in small and medium construction organisations there is the need for drivers such as strategic planning, building trust among stakeholders, attracting and retaining competent talents within the company, and creating a competitive advantage that will help them grow in terms of the type of projects they handle. It is believed that if these drivers

are put in place, SMEs can properly adopt KM practices within their everyday activities and by so doing acquire, retain and transfer knowledge properly. Through this also, better service delivery can be achieved, and more client satisfaction can be obtained. While this study contributes to the body of knowledge by bringing to light of the key drivers of KM in small and medium construction companies, care must be taken in generalising the result of the study due to some identified limitations. The study was limited to a single province within the country, thus, there is a need for further studies in other provinces within the country, to compare results. There is also the need for further studies conducted with a much larger sample size than what is obtainable in this current study.

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# The Challenges of the Construction Workforce Shortage: the case of Croatia

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## Abstract:

The construction workforce is essential to the construction industry, which is known globally for its generation of jobs at different skill and professional levels. The world's construction industry is currently experiencing a rapid recovery after the 2008 global crisis. This positive growth is also noticeable in Croatia. Nevertheless, the industry is experiencing a considerable skilled workforce shortage as well. This paper provides a statistical analysis of the construction workforce in Croatia from 2008 to 2017. The Croatian construction workforce is divided into unskilled, semi-skilled, skilled, and highly skilled employees with basic school and secondary school education, non-university college degrees, and university degrees. The analysis shows that the total number of workers employed over the last 10 years decreased significantly. There was an increase in the number of unskilled workers and a decrease in the number of all other types of workers in the 2016–2017 period, reflecting the adverse events in the construction workforce market. The main causes of the current state are analysed and response strategies on how to improve the current construction labour market crisis in Croatia are proposed.

*Keywords:* construction workforce; workforce shortage; Croatian construction industry

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## 1. Introduction

As the world's construction industry experiences a rapid recovery after the financial crisis of 2008, there is a need for a large number of manual workers, both skilled and unskilled. However, the construction industry is currently experiencing a considerable skilled workforce shortage. Recent studies regarding this subject have emphasised workforce shortage as a global issue. Han *et al.* (2008) suggest that the problem is rooted in the sector's poor image, unclear career paths, lack of training and education, declining wages, and poor work environment, along with the transient nature of construction workers. There is also the problem of an aging workforce. The characteristics of the construction industry simply do not appeal to young, potentially qualified manpower.

In extant literature, research has uncovered the skilled labour shortage as the biggest problem in the global construction labour market. Indeed, skilled construction workers are still one of the main levers in construction productivity. Other types of labour shortages, such as the highly educated worker shortage, for example, have not been investigated to the same extent. In this paper, emphasis is placed on manual work and the skilled workforce shortage as a global problem. Nevertheless, other types of shortages need to be investigated as well while assessing the labour market in a particular country.

The consequences of the skilled workforce shortage include substandard project performance and higher costs. Among the reasons for increased costs are the expenses of recruitment, training, and retaining the labour force in the construction industry (Han *et al.*, 2008). Other reasons include the tendency of unskilled workers to deliver poor quality and low productivity, which results in late project completion (Abiola, 2004; Bilau *et al.*, 2015). The mitigation of such consequences is possible (and needed) through various strategies such as filling the deficiency of new and skilled workers and replacing aging workers.

The problem of the skilled workforce shortage is discussed through an analysis of the workforce in the construction industry. Considering this problem is global, this needs to be investigated in specific markets such as in the construction workforce market in Croatia. To confirm the workforce shortage, which is also noticeable in Croatia, this paper analyses data collected from the Croatian Central Bureau of Statistics. Furthermore, existing response strategies in Croatia are investigated and commented on. Finally, the improvement of existing strategies and the introduction of new ones are proposed based on data collected from the existing literature.

## **2. Workforce in construction**

A decade after the financial crisis of 2008, the construction industry is experiencing a global recovery. The production value in construction has been rising continuously since 2013 in the European Union (Eurostat, 2019). The USA is also showing a positive rate since 2014 (US Census Bureau, 2018). In China, total nationwide investment in fixed assets doubled in the period 2008–2013 (EU SME Centre, 2015). In Croatia, this trend started later, but is also noticeable. From the data from the Croatian Central Bureau of Statistics (2018a), after 2015, volume indices of construction work started to increase. However, researchers have been warning about the consequences of global growth since the last construction bloom before the crisis of 2008. Dainty *et al.* (2004) and MacKenzie *et al.* (2000) mention that as a result of the growth, the industry is expected to experience considerable skills shortage. Today, this problem is prevalent and growing. According to the results of an industry-wide survey released by Autodesk and the Associated General Contractors of America (AGC of America, 2018), 80 per cent of construction firms report that they are having a hard time filling hourly craft positions that represent the bulk of the construction workforce. Association officials in that report state that shortages pose a significant risk to future economic growth. In another report, analysing the productivity change across Europe and the USA, Farmer (2016) concludes that the shortage of construction workers is a global problem.

### *2.1 Skilled workforce shortage*

Olsen *et al.* (2012) consider that a skills shortage occurs when the demand for workers for a particular occupation is greater than the supply of personnel who are qualified, available, and willing to work under existing market conditions; and, when the supply is greater than demand, there is a surplus.

Chini (1999) describes skilled craftspeople by their reliance on their mechanical skills and their emphasis on production. He also claims that there is no other individual on any given site

that possesses a more specialised and complete understanding of a trade than the skilled craftsman. Craftspeople typically have some type of formal training in their crafts and have been working in the field for many years. In addition, Bilau *et al.* (2015) (according to: Medugu *et al.*, 2011; Rafee, 2012) claim that craftspeople in the construction sector play an essential role in the survival and development of the sector as they are directly involved in construction operations. This can be explained by the fact that when qualified skilled craftspeople are involved in some action, it tends to eliminate the concern for poor quality, low productivity, and late project completion by reducing rework (Bilau *et al.*, 2015). Another survey conducted by Lim and Alum (1995) identified three potential concerns affecting construction productivity as: (a) difficulty in the recruitment of supervisors, (b) difficulty in the recruitment of workers, and (c) a high rate of labour turnover. This highlights that despite the advances in the construction industry, construction labour remains an essential aspect of construction. In fact, research papers have identified the skilled workforce shortage as a serious problem for the construction industry in several countries across the world (Oseghale *et al.*, 2015; Olsen *et al.*, 2012; Chan and Dainty, 2007; MacKenzie *et al.*, 2000). Nevertheless, these papers do not provide comprehensive response strategies for mitigating the skilled workforce shortage.

### **3. Workforce in Croatia**

The Croatian construction market has gone through drastic changes in the last decade. After a period of constant growth during 1998–2008, the Croatian construction sector experienced a crisis that lasted six years (2009–2015). After 2015, the Croatian construction sector once again started to recover. The big ‘boom’ in the Croatian construction sector in the period 2000–2008 resulted in an increase in Gross Domestic Product (GDP) from 4.2 to 7.3 per cent as well as an increase in employment among legal entities by 61.1 per cent (Lovrencic Butkovic and Mistic, 2014). This growth was mainly levered by major infrastructure projects such as highways (Djukan *et al.*, 2015; Lovrencic Butkovic and Mistic, 2014; Ceric *et al.*, 2009). The recession of 2008 halted this trend of strong growth. The results were: rising unemployment, a decline in real wages, the development of consumer pessimism, and the weakening of domestic production, among other factors (Lovrencic Butkovic and Mistic, 2014). One big change for Croatia in 2013 was its accession to the European Union. This encouraged investments in the construction sector as well. Nevertheless, the first positive changes only began after 2015, when the sector’s indicators started to grow following the recovery of the European Union’s economy. As shown in Table 1, volume indices for construction work and the sector’s share in GDP show positive growth after 2015.

Table 1. Volume indices of construction work and sector's share in GDP (2008–2018)  
(source: Croatian Bureau of Statistics, 2018a; Buturac, 2013–2018)

Year	Volume indices of construction work (Ø 2015 = 100)	Construction sector's share in GDP (%)
2008	191.0	7.3
2009	179.2	6.8
2010	148.5	5.7
2011	131.6	5.2
2012	114.4	4.7
2013	107.9	4.5
2014	100.5	4.3
2015	100	4.2
2016	103.3	4.3
2017	105.1	4.3

The increase in the volume indices of construction work indicates an increase in demand for construction workers, both skilled and unskilled. To investigate the current workforce market in the construction sector of Croatia, statistical analysis is provided in the next section.

### 3.1 The workforce market in Croatia

As the skilled workforce shortage is a global problem, it has also been expected in Croatia. In fact, a few years ago, the Croatian Chamber of Civil Engineers expressed their concerns about the construction workforce shortage in Croatia and appealed for the implementation of urgent measures for strategic employment in the sector (Djukan *et al.*, 2015). Although it is a well-known issue, as far as the authors are aware, there is no research on workforce shortage in Croatia that proposes solutions to this problem. Therefore, this paper provides important data and possible response strategies that Croatian construction companies can use. The analysis of the data collected from the Croatian Bureau of Statistics is carried out to show the scale of the problem. The period of analysis is set as 10 years (2008–2017). First, the trend in the total number of persons employed in the construction sector is analysed (Figure 1). The data show that the Croatian construction industry at its peak year (2008) employed 145,656 workers. In the period of crisis, 2009–2015, the number of workers fell drastically by 39 per cent. The construction market lost 56,925 employees in that period. After 2015, employment started to slowly rise, reaching 93,986 workers in 2017. However, the 5,255 workers that entered the market during last two years were not enough to cover all the losses during the period of crisis.



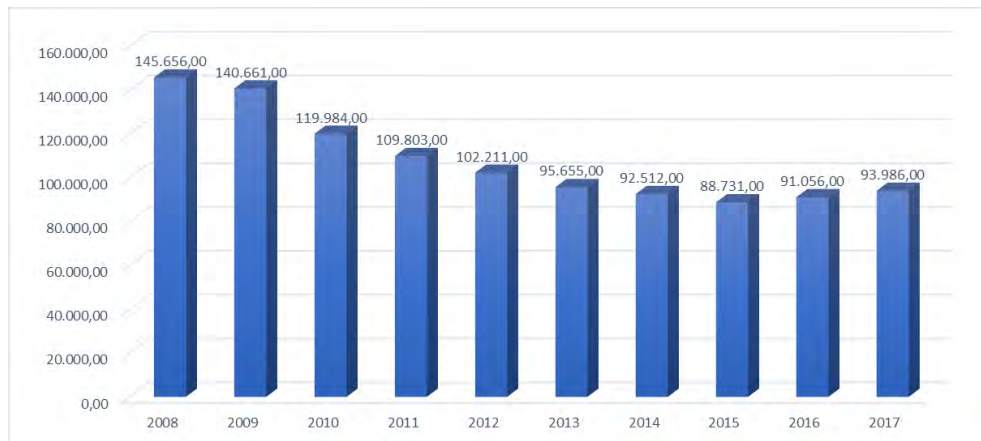


Figure 1. Total number of workers employed in the Croatian construction sector (2008–2017) (source: Croatian Bureau of Statistics, 2009–2018a, processing by authors)

Second, the trend in skill levels among construction workers is analysed. The Croatian construction workforce is divided into unskilled, semi-skilled, skilled, and highly skilled employees with basic school and secondary school education, non-university college degrees, and university degrees (Croatian Bureau of Statistics, 2009–2018a). Unskilled workers are those without any formal or informal education in construction. Semi-skilled workers are unskilled workers who have completed some short educational course in construction. Skilled workers are those with high school education of three years. Highly skilled workers are those who have also passed craft-specific examinations in their field of work. Workers with secondary school degrees are those who have completed some kind of high school program of four years. Other terms, employees with basic school education, non-university college degrees, and university degrees, are self-explanatory.



Figure 2. Number of workers employed in the Croatian construction sector by educational attainment (2008–2017): unskilled, skilled, secondary school education (source: Croatian Bureau of Statistics, 2009–2018a, processing by authors)

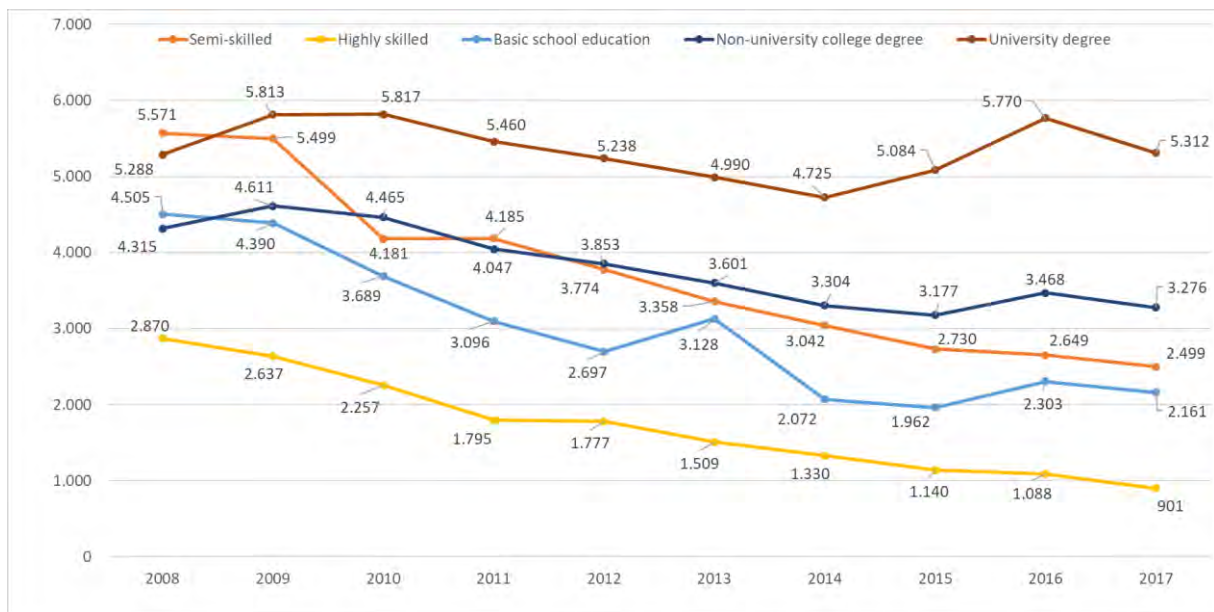


Figure 3. Number of workers employed in the Croatian construction sector by educational attainment (2008-2017): semi-skilled, highly skilled, basic school education, non-university degree, university degree (source: Croatian Bureau of Statistics, 2009–2018a, processing by authors)

As seen in Figures 2 and 3, the number of semi-skilled, skilled, and highly skilled workers has been decreasing continuously since 2011. However, the number of unskilled workers has grown by 8 per cent in the 2015–2017 period. Figures 2 and 3 show that in the 2015–2016 period, the number of workers with basic school and secondary school education, non-university college degrees, and university degrees increased, only to slightly decrease again in 2017. The simple inference is that only the number of unskilled workers increased slightly in the 2016–2017 period, while the number of all other skill level workers decreased. In the context of the increase in the volume indices of construction work in the same period (shown in Table 1), this clearly indicates a shortage of skilled workers as well as a shortage of highly educated workers. Nevertheless, this analysis has its limitations as different methods are used to collect data on the total number of workers employed and on the workers by educational employment. For example, in 2017, the qualifications of 31,024 workers employed in the construction sector were unknown to the Croatian Bureau of Statistics; thus, they were employed but not accounted for in terms of qualifications.

There are various causes for the worker shortage in Croatia. One reason for the decreasing number of educated workers even in the period of the sector’s growth can be found in the emigration of the working population (Djukan *et al.*, 2015). Economic and political emigrations started after Croatia’s accession to the European Union. This enabled young, skilled, and highly educated individuals to find new employment in more developed countries with better organised and motivating environments. Croatia had 149,559 emigrants in the 2013–2017 period and only 62,260 immigrants. The total loss of people through emigration amounted to 87,299 in this four-year period (Croatian Bureau of Statistics, 2018a). According to Pokos (2017), the numbers are even more serious because the Croatian Bureau of Statistics counts only emigrants that have officially ‘signed out’ their residence in Croatia; but, in reality, people

leave the country more often without that legal step. The working population (20–64 years old) constituted 74% of the total number of emigrants in 2017 (Croatian Bureau of Statistics, 2018b). However, emigration, in general, is only triggered by a lack of satisfactory working conditions in Croatia. The construction sector is especially unappealing for potential employees. With its strongly fragmented nature (Lovrencic Butkovic and Mistic, 2014), average monthly pay of 19 per cent below the country's average (Croatian Bureau of Statistics, 2018a), general poor image caused by corruption (Glavinja *et al.*, 2017), a culture of clans, a hierarchy rather than a market and adhocracy orientation (Sandrk Nukic and Huemann, 2016), and inadequate human resource management, the Croatian construction sector is having a hard time attracting new skilled and educated employees.

### 3.2 Existing retention measures

In Croatia, the workforce shortage has been well documented in recent newspaper articles. The massive emigration wave and aging population have caused serious public concern for Croatia's economic sustainability. Again, articles show that the construction sector has been the most affected by the workforce shortage (Bogdan, 2018; Barisic, 2017; Stapic, 2017).

The Croatian Employment Service is actively working on measures of retention for existing workers. Some of the existing projects include active inclusion and improvement of access to the labour market, the sustainable integration of young people into the labour market, implementation of local employment initiatives, and strengthening the availability and quality of information and services in the labour market (Croatian Employment Service, 2015). However, the measures are not directed at the construction sector alone and, therefore, are not as valuable for resolving the problem of the workforce shortage in that sector. Another more effective measure has been the retraining of unemployed people, also conducted by the Croatian Employment Service. Retraining enables unemployed people to change their professions with the help of Croatian Employment Service financing.

In addition, the Government of the Republic of Croatia is working on measures to attract new foreign employees. Annual quotas for the employment of foreign workers have been increasing year over year. Figure 4 shows the number of authorised permits for foreign workers in the construction sector. In the 2016–2019 period, the number increased from 500 to 17,800 permits, which represents 43 per cent of the total number of authorised permits in 2019. The most sought after construction professionals are carpenters (2900 permits), masons (2900 permits), unskilled construction workers (2550 permits), assemblers (2000 permits), steel-benders (1200 permits), concrete workers (700 permits), and plasterers (700 permits). Data show that Croatia lacks a large number of skilled workers and also unskilled workers to a smaller extent. The employment of foreign workers can be a short-term measure for mitigating the workforce shortage in Croatia, but, in that case, specific human resource management strategies need to be implemented by construction companies. In fact, different cultural characteristics and possible skill mismatches are to be expected when employing foreign workers.

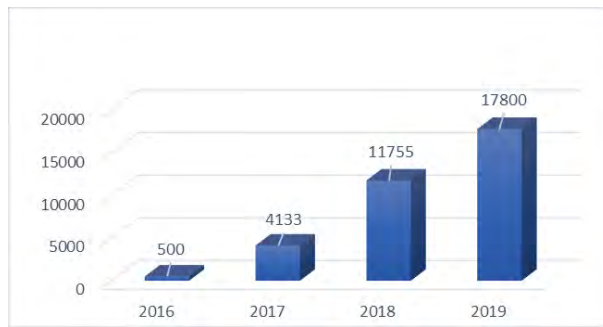


Figure 4. Annual quotas for employment of foreign workers in the Croatian construction sector (2016–2019) (source: Narodne novine, 2018a, 2018b, 2017, 2016; processing by authors)

The Croatian Chamber of Economy supported the measure of the employment of foreign workers in their recent report (Croatian Chamber of Economy, 2017). Nevertheless, they emphasised that this is only a short-term, ‘fire fighting’ measure. They further appealed for changes in the education system as the only possible long-term solution for the workforce shortage in construction. They also mention dual vocational education and retraining as valuable mitigation measures. Dual vocational education has, in fact, been advocated by the Croatian Ministry of Science and Education and through the adoption of two documents: Model of Croatian Dual Education (Croatian Ministry of Science and Education, 2018a) and Experimental Program: ‘Dual Education’ (Croatian Ministry of Science and Education, 2018b). The experimental program is planned for implementation in the 2018/2019 and 2019/2020 academic years. Dual education is characterised by the direct involvement of employers in the academic system. Students learn both in educational institutions and in the work place. The result is a more effective learning process and partial fulfilment of labour market demands by employing young and motivated workers.

Another important aspect to attracting new entrants to the construction labour market is a change in the construction sector’s poor image. To this end, construction workers’ rights are being protected by a Trade Union in the construction industry in Croatia. The Trade Union and the Construction Employers’ Association have established collective bargaining agreements for the construction industry to implement better working conditions and increases in the wages of construction workers. The Union and the Construction Employers’ Association believe that increases in wages are essential for attracting new employees into the market (Varosanec, 2019).

#### 4. Suggested response strategies for the Croatian construction labour market

To improve the current labour market crisis in Croatia, a set of appropriate response strategies is suggested. They are based on the current measures proposed by the State and analysis of other countries with similar problems (Olsen *et al.*, 2012; Han *et al.*, 2008; Clarke and Herrmann, 2007; Dainty *et al.*, 2004; Gomar *et al.*, 2002; Kashiwagi and Massner, 2002; Chini *et al.*, 1999). The analysis uncovered three short-term and five long-term strategies appropriate for implementation in Croatia. They are listed in Figure 5.

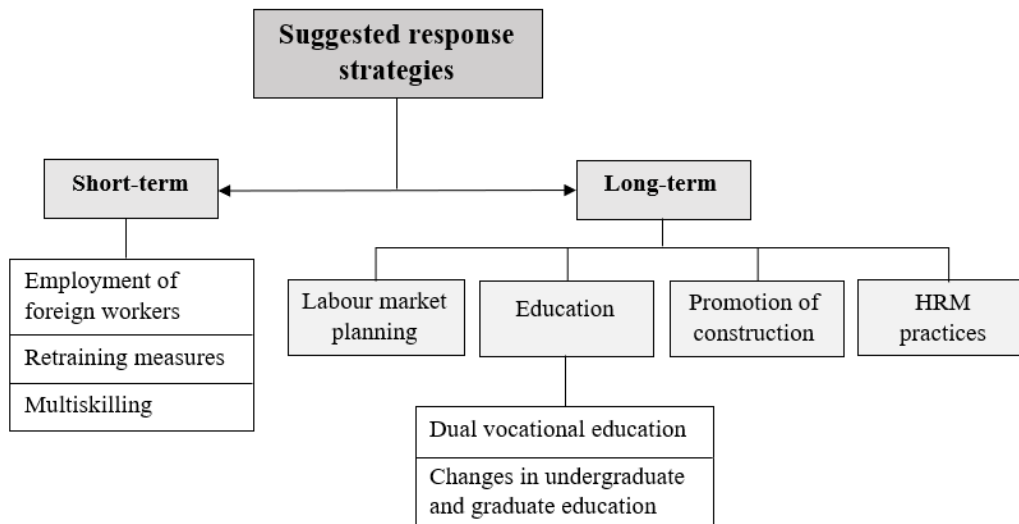


Figure 5. Suggested response strategies for workforce shortage mitigation in Croatian construction industry

The suggested short-term strategies are foreign worker employment, retraining, and multiskilling. Foreign worker employment and retraining are existing measures in Croatia, and multiskilling is a strategy that can address the workforce shortage problem by utilising existent workers more efficiently (Gomar *et al.*, 2002). All of these can provide short-term solutions to fill vacancies, but changes in work organisation and management are crucial for their successful implementation.

Long-term measures are the real levers of change. To enhance the current poor image of the construction industry, ‘promotion of the construction profession’ in basic school, high school, and college is needed (Chini *et al.*, 1999). The motivation for suggesting this strategy is that the promotion of construction as a profession should be planned and organised in a more strategic way to generate real change in the construction sector’s image. Furthermore, there is a need for ‘labour market planning’ at the national level (Dainty *et al.*, 2004). An example of the successful implementation of this measure into a comprehensive strategic labour market plan can be seen in Germany (Clarke and Herrmann, 2007). Changes are also essential in the education system, which is highly unproductive in Croatia. The lack of inclusion of employers in the education system has led to an insufficient number of new employees into the industry. Changes should be implemented in undergraduate and graduate educational programs (Kashiwagi and Massner, 2002), and in vocational education as well (Croatian Ministry of Science and Education, 2018a, 2018b). Efforts have already been made to start a new dual vocational education program in Croatia, following the model well established and verified in Germany. Together, these education strategies should encourage more young people to enter the industry. Last, to overcome the poor image of the construction profession, there is a need for construction companies to implement strategic human resource management (HRM) practices in their everyday work environment. An increase in wages would be one aspect of this strategy, but other non-material compensation should be introduced as well by construction company management. This is where construction companies can learn from other disciplines. Some of the possible compensations could include: bonuses, overtime opportunities, loyalty rewards, and promotions as incentives (Chini *et al.*, 1999).

## 5. Conclusions

In light of the current global growth in the construction industry, the lack of a qualified workforce has become a serious issue all over the world. Researchers have been warning about skilled labour shortages for decades, but no scientific answer has been given in the discussions on this subject. The conclusions in previous research highlight the skilled construction labour shortage as a global problem.

This paper uses statistical data collected from the Croatian Bureau of Statistics to investigate the scale of the construction workforce shortage in Croatia. The contribution of this analysis is the verification of the global skilled workforce shortage identified in other research, and the discovery of adverse trends in the Croatian construction labour market: an increase in the number of unskilled workers and a decrease in the numbers of workers with other educational attainment. As argued earlier, these trends result in poor quality, low productivity, and late project completion. Their stabilization is essential for the Croatian construction industry success. The limitations of the analysis arise from the different methodologies used in the collection of the data on the total number of workers employed and on the number of workers by educational attainment. For this reason, future research should concentrate on the unification of such data and a more detailed analysis to uncover the real extent of the problem.

Finally, the appropriate response strategies for the construction labour market crisis in Croatia are suggested based on the literature analysis and knowledge of the current characteristics of the Croatia construction sector. Short-term strategies include foreign worker employment, retraining, and multiskilling. These are mainly intended as a means to quickly fill vacancies, but their impact is only short term and should be supplemented by a variety of long-term strategies. The recommended long-term strategies for the Croatian construction labour market crisis are the implementation of dual vocational education; changes in undergraduate and graduate education programs; the promotion of construction as a profession among basic school, high school, and college students; labour market planning; and the implementation of HRM practices in construction companies. Nevertheless, verification of these conclusions is needed, and future research should offer more answers to resolving the identified construction labour market crisis in Croatia.

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# Effects of Training and Development on Employee Performance in a South African Construction Company

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## Abstract:

This paper examines human resource management (HRM) personnel's perception with regards to the effect of training and development (T&D) on employee's performance in a grade 9 construction company in South Africa. This was done with the view to highlight the importance of T&D within the construction industry and by extension improve employee's performance through quality T&D. The study adopted a quantitative research approach and the data were collected from HRM department using structured questionnaire. The data gathered were analysed using percentage for the demographical information of the respondents, while mean item score, and standard deviation were used to rank the identified effects of T&D. Findings from the data revealed that T&D increases job knowledge, enhances performance and productivity of the organisation, and it is essential for construction employee's performance. Furthermore, the findings revealed that T&D brings positive attitude in employees, enhances their performance and productivity, and improves their competency level. The study contributes to the body of knowledge as it highlights the key impact T&D has on employee's performance.

*Keywords: training and development; employee performance; human resource management; personnel management*

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## 1. Introduction

The effect that training and development (T&D) has on both employee and organisational goals has been a significant debate among scholars and professionals (Brum, 2007). A school of thought argues that T&D is a tool that can lead to higher levels of employee retention while the other argues that T&D leads to an increase in turnover (Colarelli and Montei, 1996; Becker, 1993). Irrespective of which side one falls within this debate, most professionals agree that employee training is a multifaceted human resource (HR) function that has great impact on the success of the company. Moreover, Falola et.al, (2014) noted that T&D is indispensable strategic tool to increase employee performance. T&D is of paramount importance as it affords competitive advantage for an organisation over its competitors and aids employees to better perform at their jobs. Also, it allows organisations to compete in the new economy and to meet the ever-changing challenges of the world of work (Warnich et al., 2014).

The continued need for individual and organisational development stems from the dynamics of increasing productivity, enhancing employee skills and knowledge, and maintaining superiority in the workplace (Edens and Bell, 2003). More so, previous research on human resource development (HRD) noted that the selection, and training of well performing employees is linked to the response to the need for higher productivity and

performance within the organisation (Garavan et al., 1999; Hodgetts et al., 1999; Losey, 1999). Vemic, (2007) stated that knowledge is becoming basic capital and a reliable source of sustained competitive advantage. Likewise, the emphasis of sustainable human capital in the workplace urges companies to strive for achieving and maintaining competitive advantage through its human capital (HC) as well as finding ways of knowledge gaining of that HC. Therefore, it can be concluded that the practice of T&D and, effective management of HR promotes continuous knowledge and skills transfer, proactive behaviour and knowledge innovation.

Based on the above, this paper was aimed at examining the effects of T&D on employees' performance and productivity. This was done with the view to identify the importance of T&D within the construction industry and by extension improve employee's performance through quality T&D initiatives.

## **2. Literature Review**

A study by Devi and Shaik, (2012) conveys training as being modern-day oriented; with a focus on employees' current job tasks and enhancing specific skills to immediately perform their jobs. While development has a holistic view, focused on enhancing behaviours, improving performance and future jobs of the organisation. Snell and Bohlander (2012), opined that training is an initiative orchestrated by a company in order to facilitate learning amongst its workers, and development enhances an individual's skills and abilities for future responsibilities. In the same light Aguinis and Kraiger, (2009) differentiated training from development by highlighting training as "the systematic approach to affecting individuals' knowledge, skills, and attitudes in order to improve individual, team, and organisational effectiveness" while development is "the systematic efforts affecting individuals' knowledge or skills for purposes of personal growth or future jobs and/or roles." Furthermore, Arnoff (1971) described T&D is the driving force to employee initiative and creativity, which also assists in preventing manpower obsolescence, due to attitude, age, or the employee's inability to adapt to technological changes. While, Obisi (2001) defined T&D is a process through which the knowledge and aptitude of an employee is enriched. Hellriegel et al, (2001) reiterated that the T&D of employees enhances productivity and performance, effective utilisation of HR, organisational objectives and goals are met, diminished expenses because of reduced employee turnover, lessened errors, accidents and absenteeism, proficient and versatile personnel and maintenance of the current staff. Throughout literature authors have described T&D in many ways. However, the commonalities amongst the studies is the skill and educational enhancement to bring about permanent change in an individuals' knowledge, capabilities or attitude.

According to Edens and Bell (2003) T&D is one of the most universal approaches for increasing the productivity and performance of employees and communicating organisational goals to new employees. Likewise, T&D enhances employee morale improvement and ability to adapt to change, (Katcher and Snyder, 2003). A comprehensive T&D program is of paramount importance as it gives competitive advantage for an organisation over its competitors and aids employees to better perform at their jobs. Organisations pursue workplace

learning strategies that are an optimal answer to complex business challenges and which enable employee competencies (Garavan and McGuire, 2001). Hence, T&D remains one of the important and widely driven mechanisms toward the employee and for the successful growth of the organisation (Elnaga and Imran, 2013). Tahir et al. (2014) stated that in pursuit of organisational goals, T&D practices are not only beneficial to the organisation but to the employees at large. On an organisational perspective T&D increases profit margins and helps retain talented employees thus accomplishing the firm's goals and maintaining competitive advantage. For employees the overall benefits gained from T&D are; improved job satisfaction and confidence, higher motivation, increased competences in processes, which results in financial gain. Also, aids employees to be receptive to new technological systems, and innovative strategies and products (Tahir et al., 2014).

### *2.1 Employee Performance*

Armstrong (2000) observed that employee performance is generally looked at in terms of outputs. Though, it may also be viewed based on an employee behavioural perspective. Therefore, affirming the statement by Aguinis (2009) that "performance does not include the results of an employee's behaviour, but only the behaviours themselves". Meaning, it is not based on the outcomes of their work but on the employees' behaviour. More so, gratified employees yield higher performance levels, which makes it easy for the organisation to motivate them and subsequently achieving organisational objectives, (Kinicki and Kreitner, 2007). Similarly, the acknowledgment of substantial training practices aids management to establish a conducive working environment that increases employee performance and their motivational levels. According to Huselid (1995) the efficiency of HRM will transfer on the behaviour of the workforce. Hence, Carlson et al. (2006) proposed five HRM performance enhancing practices which are; recruitment package, T&D, compensation and benefits, performance appraisals, and employee motivation. Additionally, Teseema and Soeters, (2006) study based on eight HRM practices showed that recruitment and selection practices, placement practices, training, compensation, employee performance evaluation, promotion, grievance procedure and pension or social security have an effect on employee performance.

In conclusion, with the aid of existing literature, if certain HRM practices are not efficiently employed by the organisation, the performance of the employees would be stagnant. Hence it is important for companies seeking ways to help low performing employees, (Elnaga and Imran, 2013).

### *2.2 Relationship between Training and Development and employee performance*

With increasing competition, rapidly changing economic environment, globalisation and deregulation of markets, organisations are required to constantly revise their products, services, HR approaches and increase productivity (Becker, 1996). Therefore, as the organisation progresses, the implementation of T&D is imperative in enhancing performance and productivity (Nassazi, 2013). According to Pfeffer (1994) well-trained personnel are more capable of attaining performance goals and gaining competitive advantage in the market. Agreeably, previous literature indicates that employee performance is a vital tool for organisational performance since employee performance influences the overall performance in

the organisation; the study by Guest, (1997) and Swart et al., (2005) focused on the general outlook of organisational performance, while Purcell et al., (2003) and Harrison (2000) looked at performance with regards to employee performance. T&D is defined as “the process of enabling employees’ to complete tasks with greater efficiency, thus considered to be an important element of strategically managing the performance HR” (Delaney and Huselid, 1996; Lawler, 1993). Furthermore, T&D aids in the reduction of employee dissatisfaction, absenteeism, turnover, and it offers a sense of attainment and knowledge that their skills are being developed, (Pigors and Myers, 1989).

As depicted by Harrison (2000) in his study, learning through T&D has a great influence on the organisation’s performance through the increased performance of its workers. Likewise, previous investigations show the correlation of T&D and employee performance (Nassazi, 2013; Tahir et.al, 2014). Therefore, applicable T&D interventions are needed to develop certain skills of the employees to enhance workforce performance (Swart et al. 2005). However, for the successful implementation of T&D programs, adequate planning is required, (Nassazi, 2013). Kenney and Reid (1986) defined planned training as “the deliberate intervention aimed at achieving the learning necessary for improved job performance.” Furthermore, in their study Kenney and Reid (1986) suggested that planned training should consist of the following steps; (1) Identify and define training needs; (2) Define the learning required in terms of what skills and knowledge have to be learnt and what attitudes need to be changed; (3) Define the objectives of the training (4) Plan training programs to meet the needs and objectives by using right combination for training techniques and locations; (5) Decide who provides the training; (5) Evaluate training and (6) Amend and extend training as necessary. Affirming the aforementioned steps is Arnoff (1971) who indicated that before offering training to employees, the need and objectives of the training programs should be identified.

### **3. Methodology**

The study adopted quantitative methods in examining the perception of training and development in a South African construction company. As per the Construction Industry Development Board (CIDB) grading system, the construction company is a Grade 9 contracting firm, thus classifying the company as a large construction company. The quantitative approach employed for this study has enabled the investigation of relationships among variables, using descriptive and inferential statistics. A structured questionnaire was designed and distributed to the Human Resource Management Department. Out of the twenty-seven purposefully selected respondents, twenty-seven were returned thus yielding a return rate of 100%. Pawar (2004), highlights that a questionnaire may consist of open-ended and closed-ended questions with a definite purpose that is correlated with the objectives of the research. Open-ended questions require respondents to document their thoughts and feelings, while closed-ended questions are limited to and guided by the options given by the researcher. The questionnaire for this study comprises of closed-ended questions using a five-point Likert scale, to measure the attitudes of the respondents by choosing a factor from a number of factors ranging from ‘Strongly Agree to ‘Strongly Disagree’.

The consistency of results across items was measured with Cronbach's Alpha, which yielded an alpha value of 0.876. There are diverse reports from researchers about the tolerable values of alpha, which range from 0.70 to 0.95 (Bland and Altman, 1997; DeVellis, 2003; Nunnally and Bernstein, 1994). Nevertheless, the study by George and Mallery (2003) indicates that any value above 0.7 is acceptable. Hence, the Cronbach Alpha for this study proves that the questionnaire used is reliable. Also, the data gathered were analysed using percentage for the background information of the respondents, while mean item score (MIS), and standard deviation (SD) were used to rank the identified perceptions as rated by the respondents. More so, factors with MIS of 3.00 and above were considered significant perceptions of training and development within the construction company.

#### **4. Findings and Discussions**

Upon the review of existing literature, factors on training and development were identified. The respondents were presented with these factors to rate based on their perception of training and development. The results from the data revealed that all the factors were significant apart from one factor. Table 1 indicates the employees' perception on training and development. The results from the data revealed that T&D increases job knowledge ranked first (MIS=4.33; SD=0.78); T&D enhances performance and productivity of the organisation ranked second (MIS=4.19; SD=0.68); T&D is essential for construction employees ranked third (MIS=4.15; SD=0.86); T&D brings positive attitude in employees ranked fourth (MIS=4.11; SD=1.01); both T&D enhances performance and productivity of the employees ranked fifth (MIS=4.04; SD=0.76). Furthermore, the table indicated that T&D improves competency levels was ranked sixth (MIS=4.00; SD=1.00).

The study by Aguinis and Kraiger, (2009) agrees with the above findings on T&D. In their study, they highlighted that T&D affects individuals' knowledge, skills, and attitudes in order to improve individual personal growth, team, and organisational effectiveness. Likewise, the suggestion by Harrison (2000) learning through T&D has a great influence on the organisation's performance through the increased performance of its workers. Swart et al (2005) noted that T&D interventions are needed to develop certain skills and abilities of the employees to enhance workforce performance. However, the study of Colarelli and Montei, (1996) disagree with the findings and suggests that T&D leads to increase in employee turnover. Thus, the greater the chance of employee turnover, the less likely a company will invest in T&D. Similarly, the research conducted by Brum, (2007) indicated that a company incurs direct and indirect costs due to T&D and the return on investment is based on the increase in worker output and productivity upon completion of the training.

Table 1. Effects of Training and Development on Employee performance

Effects of Training and Development	MIS	SD	Rank
T&D increases job knowledge.	4.33	0.784	1
T&D enhances performance and productivity of the organization.	4.19	0.681	2
T&D is essential for construction employees.	4.15	0.864	3
T& D brings positive attitude in employees.	4.11	1.013	4
T&D enhances performance and productivity of the employees.	4.04	0.759	5
T&D improves competency levels	4.00	1.000	6
T&D reduce consumption of time and costs	3.96	0.706	7
Performance and productivity greatly depend on T&D	3.96	0.898	8
Employees consider T&D vital for jobs.	3.89	0.847	9
T&D reduces the stress of the employees.	3.78	1.050	10
Training interventions are clearly measurable.	3.44	0.934	11
Analysis of poor performance is undertaken before training employees.	3.00	1.074	12
T&D is compulsory for all employees.	2.78	1.423	3

## 5. Conclusion

The current study revealed the effect of T&D on employee performance as perceived by HRM personnel in a South African construction company. The Findings from the data revealed that T&D increases job knowledge, enhances performance and productivity of the organisation, and T&D is essential for construction employees. Furthermore, the data revealed T&D brings positive attitude in employees, enhances performance and productivity of the employees and improves competency levels. Therefore, it is imperative for firms to design and implement T&D programs with clear goals and objectives that will be beneficial to both the individual and firm. Moreover, the firm needs to know the purpose and objectives of the training, the knowledge, skills and abilities the employees would learn at the end of the training program and whether the employees will be able to effectively achieve the required performance targets on job. The study contributes to the body of knowledge on T&D of employees and its impact performance.

Prior literature on HRM reveal that, employees are the most important resource and asset of an organisation and perform better when adequately trained. Hence, the relationship of T&D and its effect on employee performance should be based on the need of the organisation, likewise, benefiting the employee in terms of performance, skills, knowledge which will in turn help organisations achieve their objectives and sustain competitive advantage. Likewise, employees would have a better career life and opportunities for promotion within the company. Therefore, the purpose of this study was to investigate the relationship between T&D and Employees' performance. This study may be extended towards the relationship between organisational performance and other related HRM practices, also of T&D and employee commitment, turnover and organisational loyalty, with underpinning variables such as work environment, opportunities for promotion, salary increment and better benefit packages. Further, a study on knowledge management, skills transfer, and the concept of a learning organisation may be conducted. The future studies must not be limited to a single construction company in South Africa but to the construction industry in South Africa.

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# Construction Professionals' Motivation: Case Study of Turkey

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## Abstract:

Motivation is one of the key factors that have an influence on individuals to improve their productivity. Therefore, the motivation of workers has been a focus of debate that is of considerable interest to participants in the construction industry. However, although the motivation of construction professionals, namely architects and civil engineers, may also enhance the performance of a construction project, this area is mostly ignored in the motivation literature. The objectives of this study are: (1) to understand which motivators are considered to be important by civil engineers and architects; (2) to explore the existence of significant differences between civil engineers' and architects' motivators. For this purpose, a questionnaire survey was administered to Turkish architects and civil engineers to collect data on their perceptions of the importance of different motivators. The case of Turkey is investigated because a large number of Turkish contractors are major players in international markets. Statistical analysis was performed on the collected data to verify that there are statistically significant differences in the perception of civil engineers and architects on some motivators. The study demonstrates the existence of a significant difference between architects' and civil engineers' motivators. Identifying the architects' and civil engineers' motivators may help construction companies in motivating their architects and civil engineers more effectively, thus developing a quality workforce.

*Keywords:* construction; architect; civil engineer; motivation.

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## 1. Introduction

It is commonly acknowledged that highly-motivated personnel may help to improve the performance of a construction project (Uwakweh, 2006; Han *et al.*, 2008; Oyedele, 2010; Jarkas, 2012). Therefore, many researchers conducted studies to shed light on the motivation of construction workers. On the other hand, a non-motivated professional may be ineffective in performing most tasks, such as making decisions, handling problems, and managing changes, which in turn can have a negative impact on the completion of the construction project (Pheng and Chuan, 2006; Seiler *et al.*, 2012). Nevertheless, studies on the motivation of construction professionals (e.g., civil engineers, architects, etc.) are rare in the motivation literature. For example, Singh (2000) measured engineers' perception about satisfaction and dissatisfaction relative to individual motivational elements by means of an indicator called the Development Index. In another study by Venkatesan *et al.* (2009), the key factors that motivate and demotivate engineers were identified by conducting a questionnaire survey. Oyedele (2010) used regression analysis in order to identify the critical factors influencing professionals' (architects and design engineers) motivation in design firms. Due to the limited

number of studies on the motivation of professionals, there is still a need for studies investigating the motivation of professionals. The purpose of this study was to understand which motivators are considered to be important by civil engineers and architects and explore the existence of significant differences between civil engineers' and architects' motivators in the context of Turkey. The case of Turkey is investigated because Turkish contractors are among the leading international contractors according to *Engineering News-Record* (Engineering News-Record, 2018). For this purpose, firstly a questionnaire survey was sent to Turkish architects and civil engineers to collect data on their perceptions of the importance of different motivators. After that, statistical analysis was performed on the collected data to confirm that there are statistically significant differences in the perception of civil engineers and architects on some motivators. To sum up, the major contribution of this research to the body of knowledge is that it explores the existence of significant differences between civil engineers' and architects' motivators which may help construction companies in motivating their architects and civil engineers more effectively.

## 2. Research Methodology

The tasks that were performed in this study can be summarized as follows: (1) conducting a literature review to identify the most-cited motivators of construction professionals; (2) carrying out a survey of Turkish architects and civil engineers to collect data on their perceptions of the importance of different motivators; and (3) performing statistical analysis on the collected data to verify whether a statistical relationship exists between civil engineers' and architects' motivators. The questionnaire used in this study comprises two parts. The first part consists of six questions about the personal characteristics of the respondents, namely, (1) age, (2) marital status, (3) education, (4) work experience, (5) type of employer, and (6) the value of the largest project that the respondent worked on. In the second part of the questionnaire, respondents are asked to rate the importance of 20 motivators. The motivators were identified by considering the perspective of professionals employed in the construction industry (e.g., Shoura and Singh, 1998; Oyele, 2010) and the perspective of professionals employed in management positions in other industries (e.g., Analoui, 2000; Antonioni, 1999). The respondents were asked to use a Likert-like scale of 1-5 in order to rate the level of importance of the motivators listed in the questionnaire, where "1" represents "not important" and "5" "very important". The target population in this study was set as the members of the Istanbul Chamber of Turkish Civil Engineers and the Istanbul Chamber of Turkish Architects, as they are the largest professional bodies of engineers and architects in Turkey. The questionnaire was sent to the members via e-mail. The reliability of the scale used in this study can be checked by using various techniques, Cronbach's alpha ( $\alpha$ ) being the most commonly used technique to determine the internal consistency of a survey when using a Likert scale (Oyedele, 2013). This method predicts the reliability of a given set (Santos, 1999; Gliem and Gliem, 2003). In addition, Carfio and Perla (2008), and Jamieson (2004) suggest that Likert data should be analyzed by using non-parametric tests. The Mann-Whitney U test is a non-parametric technique that was used in this study to test the significance of differences between civil engineers' and architects' motivators. If the  $p$  values are less than 0.05, it indicates that there is a statistically significant difference between them at 95% significance level.

### 3. Findings

A total of 179 members of the Istanbul Chamber of Turkish Architects and a total of 394 members of the Istanbul Chamber of Turkish Civil Engineers completed the questionnaire. The personal characteristics of the respondents are presented in Table 1. Based on the information presented in Table 1, the demographic characteristics of architects and civil engineers are not exactly the same but quite similar. Indeed, if one takes a look at age, marital status, education, experience in the construction industry, type of employer, and the value of the largest project that the respondent worked on, one can observe that the architect and civil engineer populations that are compared in this study are quite compatible.

Table 1. Personal characteristics of the respondents

Characteristics	Number of Respondents (%)	
	Architects	Civil Engineers
<b>Age</b>		
<35	66	60
>35	34	40
<b>Marital status</b>		
Single	54	41
Married	46	59
<b>Education</b>		
Bachelor's degree	61	57
Master's or Doctorate degree	39	43
<b>Experience in construction industry</b>		
<10 years	59	57
>10 years	41	43
<b>Type of employer</b>		
Non-contractor organizations	53	41
Contractor	47	59
<b>The value of largest project that the respondent worked on</b>		
< \$50 million	58	41
> \$50 million	42	59

In order to confirm whether the motivators and their associated Likert scale are actually measuring the motivation of construction professionals, Cronbach's alpha values were computed via the IBM SPSS Version 23. The Cronbach's alpha coefficient ranges between 0 and 1. If it is closer to 1, it indicates high reliability of the used scale. If the Cronbach's alpha value is equal to or higher than 0.60, it can be concluded that the reliability of the scale is satisfactory (Santos, 1999; Gliem and Gliem, 2003). The Cronbach's alpha coefficient calculated for each motivator are presented in Table 2. As seen in Table 2, since the overall Cronbach's alpha value for this study was found to be 0.855, which is higher than 0.60, it can be concluded that good reliability and satisfactory the internal consistency of the scale used in the questionnaire. Based on the average scores presented in Table 2, the motivators that are most important to architects and civil engineers are "job satisfaction", "achieving success in my work", "efficient collaboration with friendly and congenial teammates", and "participation in decisions that affect my area". In other words, this finding reveals that Turkish civil engineers and architects rate the same motivators as the most important motivators. It is understandable that both architects and civil engineers score high in "job satisfaction" and "achieving success in my work" because according to Schein (1990), technical/functional

individuals attach great importance to these motivators. On the other hand, high scores in “efficient collaboration with friendly and congenial teammates” and “participation in decisions that affect my area” also make sense because, according to Schein’s (1990) career anchor categories, individuals in management positions are motivated by these factors. On the other hand, architects and civil engineers attach different levels of importance to the least important motivators. “Comfortable physical work environment” and “participation in decisions that affect organizational policies” were found to be the least important motivators for architects while “working on projects of my choice” and “avoiding harm and trouble” were the least important motivators for civil engineers. This finding can be explained by the fact that many civil engineers work on construction sites and are used to coping with unfavorable weather conditions and safety hazards in different geographical locations, hence their disinterest in “projects of my choice” and “harm and trouble”; and that many architects work in design offices and are used to perform in standard office accommodations and to work as part of a design team, hence their disinterest in the “work environment” and “organizational decisions”.

Table 2. Arithmetic mean scores and “Cronbach’s alpha if item deleted” values for motivators

Motivators	Architects		Civil Engineers		Mann-Whitney U Test <i>p</i> Values
	Cronbach’s Alpha	Average Score*	Cronbach’s Alpha	Average Score*	
Recognition and appreciation from superior	0.843	4.3	0.851	4.2	0.214
Raise in salary	0.848	4.4	0.853	4.4	0.644
Opportunity for advancement and promotion	0.840	4.2	0.854	4.1	0.438
Efficient collaboration with friendly and congenial teammates	0.850	4.5	0.852	4.5	0.806
Job satisfaction	0.845	4.7	0.850	4.6	0.460
Gaining knowledge, ability and confidence	0.842	4.4	0.846	4.4	0.855
Mutual trust and loyalty between you and superior	0.840	4.4	0.848	4.2	0.051
Participation in decisions that affect my area	0.845	4.5	0.847	4.4	0.438
Upper management's awareness of my job results	0.838	4.3	0.844	4.2	0.099
Fairness in how people are rewarded for work performance	0.845	4.4	0.844	4.4	0.435
Working on projects of my choice	0.848	4.0	0.846	3.7	<b>0.001*</b>
Achieving success in my work	0.843	4.6	0.846	4.5	0.327
Impacting my subordinates positively	0.841	4.3	0.848	4.1	<b>0.019*</b>
Avoiding harm and trouble	0.844	4.1	0.847	3.8	<b>0.001*</b>
Job security	0.840	4.2	0.845	4.1	0.265
Belonging to an organization that is highly regarded	0.841	4.4	0.847	4.0	0.493
Participation in decisions that affect organizational policies	0.844	3.8	0.851	3.8	0.374
Comfortable physical work environment	0.847	3.9	0.852	3.7	<b>0.005*</b>
Task and responsibilities that are clearly specified	0.849	4.3	0.848	4.0	<b>0.006*</b>
A job where I get feedback on how I am doing	0.840	4.1	0.845	3.9	0.085

\*1: Not important; 2: Low importance; 3: Moderately important; 4: Important; 5: Very important

Turkish civil engineers rate only two motivators (i.e., “participation in decisions that affect organizational policies” and “comfortable physical work environment”) lower than “important”. On the other hand, Turkish architects rate five motivators lower than “important” which are “comfortable physical work environment”, “participation in decisions that affect organizational policies”, “a job where I get feedback on how I am doing”, “working on projects of my choice” and “avoiding harm and trouble”. The *p* values obtained from the Mann-Whitney U test are presented in Table 2 and show that there is a statistically significant difference between architects and civil engineers in some motivators when viewed by civil engineers compared to architects.

- Civil engineers attach more importance than architects (difference statistically significant at  $\alpha = 0.05$ ) to the motivators “working on projects of my choice”, “impacting my subordinates positively”, “avoiding harm and trouble”, “comfortable physical work environment” and “tasks and responsibilities that are clearly specified”. Even though Turkish architects and civil engineers rate the same motivators as the most important motivators, Damci’s (2016) study of civil engineers reveals that motivators differ when individuals’ personal characteristics are taken into consideration. The statistically significant difference in some motivators may be a result of the personal characteristics of the two groups of respondents in this study.
- There is no statistically significant difference in the most important motivators when viewed by civil engineers compared to architects. This result is understandable since both architects and civil engineers are technical individuals with managerial roles, and since the top four motivators identified in this study are quite important for these individuals.

#### 4. Conclusion

Construction professionals, namely architects and civil engineers, play an important role in managing design and construction. The success of construction projects depends on the motivation of construction professionals in making decisions, handling problems, and managing changes. Even though motivating construction professionals is an important factor in completing a construction project successfully, little research has been carried out about it. The objectives of this study are as follows: (1) to understand which motivators are considered to be important by architects and civil engineers; (2) to explore the existence of significant differences between architects’ and civil engineers’ motivators. To this end, a questionnaire survey was administered to Turkish architects and civil engineers to collect data on their perceptions of the importance of different motivators. Based on survey results, the most important motivators of architects and civil engineers are “job satisfaction”, “achieving success in my work”, “efficient collaboration with friendly and congenial teammates”, and “participation in decisions that affect my area”, indicating that architects and civil engineers are on the same page concerning motivators that are widely accepted in the literature to be of importance to many professionals (e.g., Shoura and Singh, 1998; Oyele, 2010; Analoui, 2000; Antonioni, 1999). Statistical analysis was performed on the collected data to explore whether there are statistically significant differences in the perception of architects and civil engineers on some motivators. A statistically significant difference exists in “working on projects of my

choice”, “impacting my subordinates positively”, “avoiding harm and trouble”, “comfortable physical work environment” and “task and responsibilities that are clearly specified,” indicating that this result may be a function of the personal characteristics of the groups of respondents in this study. Identifying architects’ and civil engineers’ motivators may help construction companies in motivating their architects and civil engineers more effectively, thus developing a workforce performing design and construction tasks better.

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# Market Selection Using the Integration of AHP and PROMETHEE Methods

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## Abstract:

Selecting the most appropriate market in which construction contracting companies will operate is one of the most critical decisions. Market selection decision is affected by a number of factors that should be in compliance with the strategies of a company. In most cases, this decision is made by a group of top managers. Therefore, it can be considered as a group multi attribute decision making (GMADM) problem. This paper proposes an integrated decision approach, which employs analytic hierarchy process (AHP) and preference ranking organization method for enrichment evaluations (PROMETHEE) together, for solving the market selection problem. In the proposed approach, AHP is used to develop the structure of the market selection problem and to determine the weights of the criteria, and PROMETHEE is employed to determine the complete ranking and perform sensitivity analysis by changing the weights of criteria. The proposed approach is applied to a problem of selecting the most appropriate market in a large-scale construction company, which mostly operates in international markets. Company management found the proposed approach useful and stated that it could be applied in future market selection problems.

*Keywords: multi attribute decision making, group decision making, sensitivity analysis, case study.*

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## 1. Introduction

Nowadays, the demand for construction industries in developing countries is high, but the situation of the markets is constantly changing due to the critical reasons that determine the balances of the economies. Many construction companies intend to expand internationally due to the domestic construction market difficulties or attractiveness of the national cross border markets (Gunhan and Arditi, 2005a). Making this decision is a process that has strategic importance and priorities (Dikmen and Birgonul, 2004; Cheng, 2005; Chen *et al.*, 2016). It plays a crucial role in the success and sustainability of companies and should be based on mathematical analysis rather than on the intuition and experience (Ozorhon *et al.*, 2006). In most cases, this decision is made by a group of top managers. Therefore, this decision can be considered as a GMADM problem.

The aim of this study is to propose an integrated decision approach for selecting the most appropriate market to enter. For this purpose, first, an extensive literature review was carried out in order to determine the factors that may affect the selection of a market. After that, an integrated approach was proposed in order to assist the company management in selecting the market. In the proposed approach, AHP is used to find the weights of the criteria and PROMETHEE is employed to determine the complete ranking and perform sensitivity analysis

by changing the weights of criteria. In order to illustrate how the proposed integrated approach can be applied in a real life project, a case study was carried out. The findings of this study revealed that the proposed integrated model can be used as a useful tool in selection of the most appropriate market.

## 2. The Proposed Approach

The proposed approach includes eleven steps, which can be categorized into two main phases. In the first phase, the market selection problem is identified. Then, the decision making group who is responsible for the company's market selection process is established. This group determines the main and sub-criteria that may affect the market selection and develops the hierarchy of the market selection problem. Thirdly, the decision making group forms pairwise comparison matrices of the market selection problem. In the final step of the first phase, the weights of the main and sub-criteria of the market selection problem are calculated by using the AHP method.

In the second phase, firstly, the decision matrix that consists of the assessments of the decision-making group members on the alternative markets is formed. In the second step, preference functions for each criterion were identified. Then, preference functions for alternative pairs were determined. After that, the preference indexes  $\pi$  for each alternative pair were computed. In the fifth step, positive ( $\Phi^+$ ) and negative ( $\Phi^-$ ) superiorities of each alternative were calculated. Then, PROMETHEE I partial priority for alternatives was determined. Finally,  $\Phi_{net}$  of eight market alternatives were calculated. These alternatives were exactly ranked by  $\Phi_{net}$  values in decreasing order.

### 2.1 Analytical Hierarchy Process (AHP)

The AHP is a mathematical theory developed to solve complex decision-making problems (Saaty, 1980). AHP enables decision makers to model complex problems in a hierarchical structure that shows the relationships among the problem's goal, main criteria, sub-criteria, and alternatives (Kumar *et al.*, 2018). As AHP is easy to understand by decision makers, it is widely used in the literature. AHP ensures that both objective and subjective assessments are included in the decision-making process.

Table 1. Saaty's Rating Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgment slightly favor one over the other.
5	Much more important	Experience and judgment strongly favor one over the other.
7	Very much important	Experience and judgment very strongly favor one over the other.
9	Absolutely more important	The evidence favoring one over the other is one of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed.

The calculation steps of AHP are (Saaty, 2008):

- *Step 1:* Identifying the hierarchical structure of the decision problem (i.e., goal, main criteria, sub-criteria, alternatives),

- *Step 2*: Forming pairwise comparison matrices that enables numerical expressions of relations between two elements in the hierarchy by using Saaty's Rating Scale (see Table 1),
- *Step 3*: Computing the consistency ratio indicating whether the matrices generated are consistent,
- *Step 4*: Finding the priorities of the alternatives according to the main criteria and/or sub-criteria.

## 2.2 Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE)

PROMETHEE is an outranking method first developed by Brans in 1982 (Brans and Mareschal, 2005). It is a method in which alternatives are evaluated based on preference functions by means of determined criteria and by making binary comparisons (Pohekar and Ramachandran, 2004). The method uses preference functions when ranking alternatives. PROMETHEE method provides partial ranking called PROMETHEE I and exact ranking called PROMETHEE II on the final number of alternatives (Macharis *et al.*, 2004). PROMETHEE's calculation steps are explained below (Athawale and Chakraborty, 2010):

- *Step 1*: Creating the decision matrix  $X$  with  $n$  number of alternatives ( $n=1, \dots, i$ ) and  $m$  number of criteria ( $m=1, \dots, j$ ),
- *Step 2*: Identification of preferred function for each criterion  $j$ ,
- *Step 3*: Determination of preference function for alternative pairs,
- *Step 4*: Determination of the preference index  $\pi$  for each alternative pair  $i$ ,
- *Step 5*: Calculation of positive ( $\Phi^+$ ) and negative ( $\Phi^-$ ) superiority of each alternative  $i$ ,
- *Step 6*: Determination of PROMETHEE I partial priority for alternatives,
- *Step 7*: Exact ranking of alternatives with PROMETHEE II, sorting by the values of  $\Phi_{\text{net}}$  ( $\Phi^+ - \Phi^-$ ), in decreasing order.

For a thorough discussion of the AHP and PROMETHEE methods, readers are directed to Polat (2016).

### 3. Case Study: Market Selection Using the Proposed Approach

In order to demonstrate how the proposed approach can be applied in a real life problem, a case study was conducted. The proposed approach has been used in the decision of the market selection of a Turkish contractor company engaged in international business. The company is listed among the top 250 international construction companies according to Engineering News-Record (Engineering News-Record, 2015). The company has about 45 years of experience in the international field. In addition, the company has many active projects in the Middle East, Turkey and North Africa. In this study, interviews were held with the four managers responsible for the company's market selection process. The model was developed based on their decisions and evaluations as well as the literature review.

#### 3.1 Decision Hierarchy of the Market Selection Problem

Having conducted face-to-face interviews with the decision makers and carried out an extensive review of literature (Lee *et al.*, 2016; Chen *et al.*, 2016; Isa *et al.*, 2014; El-Higzi, 2012; Arslan, 2010; Gunhan and Arditi, 2005a; Gunhan and Arditi, 2005b) 6 main criteria have

been identified, which include: firm characteristic (*FC*), economic attractiveness (*EA*), socio-cultural attractiveness (*SA*), ease of doing business (*ED*), competitive attraction (*CA*) and political situation (*PS*). 8 sub-criteria identified for the main criterion *FC* are: experiences /achievements in the country (*FC<sub>1</sub>*), existence of a communication office in the country (*FC<sub>2</sub>*), existence of projects / resources that are close to the country (*FC<sub>3</sub>*), existence of a good relationship with potential owners in the country (*FC<sub>4</sub>*), experience in potential project types (residence, commercial, etc.) in the country (*FC<sub>5</sub>*), capability of company to meet the technological requirements of projects in the country (*FC<sub>6</sub>*), ability of company to manage projects in the country (*FC<sub>7</sub>*) and providing company with prestige and new job opportunities because of doing business in the country (*FC<sub>8</sub>*). 4 sub-criteria identified for the main criterion *EA* are: strong and stable economic conditions in the country (*EA<sub>1</sub>*), high business volume and growth rate of the construction industry (*EA<sub>2</sub>*), high profitability of the projects in the country (*EA<sub>3</sub>*) and existence of investors / owners who are financially powerful in the country (*EA<sub>4</sub>*). 2 sub-criteria under the main criterion *SA* are: cultural closeness with the country (*SA<sub>1</sub>*) and geographical proximity with the country (*SA<sub>2</sub>*). 7 sub-criteria under the main criterion *ED* include: attractiveness of tax and monetary policy in the country (*ED<sub>1</sub>*), internationally reliability of legal system in the country (*ED<sub>2</sub>*), easy and fast bureaucratic procedures in the country (*ED<sub>3</sub>*), developed infrastructure systems (water, sewage, electricity, etc.) for start of the project in the country (*ED<sub>4</sub>*), availability of resources in the desired qualities (labor, materials, equipment, etc.) in the country (*ED<sub>5</sub>*), existence of subcontractors who can work together in the country (*ED<sub>6</sub>*) and existence of bilateral trade agreement between company's country and the country (*ED<sub>7</sub>*). 2 sub-criteria under the main criterion *CA* are: low level of competition in the country (*CA<sub>1</sub>*) and existence of a good partner to work in the country (*CA<sub>2</sub>*). 2 sub-criteria under the main criterion *PS* are: stable political situation in the country (*PS<sub>1</sub>*) and good / strong political relationships between company's country and the country (*PS<sub>2</sub>*). There are eight different market alternatives for the project, which are: *A<sub>1</sub>* (Morocco), *A<sub>2</sub>* (Oman), *A<sub>3</sub>* (India), *A<sub>4</sub>* (Pakistan), *A<sub>5</sub>* (Indonesia), *A<sub>6</sub>* (Egypt), *A<sub>7</sub>* (Qatar) and *A<sub>8</sub>* (Northern Iraq). These alternatives are countries where the company is active in the last 10 years and plans to become active within the next 10 years. The decision hierarchy of the market selection problem is presented in Figure 1.

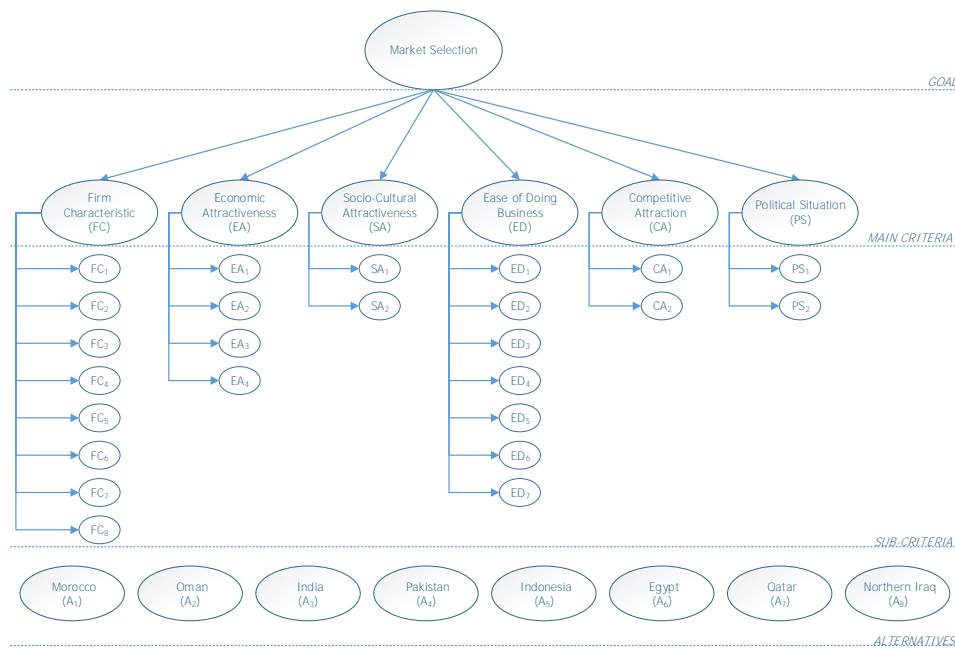


Figure 1. Decision hierarchy of the market selection problem

### 3.2 Determining the Weights of the Main and Sub-criteria of the Selection Problem

After developing the decision hierarchy of the market selection problem, the AHP method is employed to determine the weights of the identified main criteria and sub-criteria. For that reason, four decision makers were individually asked to form pairwise comparison matrices for the main and sub-criteria of the selection problem. Four pairwise comparison matrices were then aggregated by taking the geometric means of each preference in order to reach a group decision. Finally, the mathematical calculations of the AHP method were applied to find the weights of the main and sub-criteria of the selection problem. The weights of main criteria of the market selection problem are shown in Table 2.

Table 2. Aggregated pairwise matrix of main criteria for the market selection problem

Criteria	FC	EA	SA	ED	CA	PS	Weights
FC	1.00	1.26	2.11	1.06	0.54	1.57	0.179
EA	0.80	1.00	1.19	0.84	0.45	1.28	0.136
SA	0.47	0.84	1.00	0.71	0.31	0.76	0.099
ED	0.95	1.19	1.41	1.00	0.50	1.19	0.154
CA	1.86	2.21	3.22	2.00	1.00	2.45	0.311
PS	0.64	0.78	1.32	0.84	0.41	1.00	0.121

C.R.=0.003

According to the findings, the “CA - Competitive Attraction” has the highest weight in the market selection problem. It is followed by the “FC - Firm Characteristic” with second higher weight. On the other hand, the “SA - Socio-cultural Attractiveness” has the least importance on the selection process as it has the lowest weight. The consistency ratio (C.R.) of the aggregated pairwise comparison matrix is also checked. As it is below the 0.10, it can be concluded that the evaluations are consistent. The weights of sub-criteria identified under all main criteria are given in Table 3. Based on these findings, the “FC<sub>1</sub> - experiences /achievements in the

country”, “ $EA_3$  - high profitability of the projects in the country”, “ $SA_2$  - geographical proximity with the country”, “ $ED_5$  - availability of resources in the desired qualities (labor, materials, equipment, etc.) in the country”, “ $ED_6$  - existence of subcontractors who can work together in the country”, “ $CA_1$  - low level of competition in the country” and “ $PS_1$  - stable political situation in the country” have the highest weights on their own main criterion.

### 3.3 Finding the Preferences of the Market Alternatives with PROMETHEE Method

After determining the weights of the main criteria and sub-criteria of the market selection problem, PROMETHEE method was employed to determine the ranking of eight market alternatives. In the market selection problem, the preferences of four decision makers were collected to form the aggregated decision matrix. “ $FC_2$  - Existence of a communication office in the country” and “ $ED_7$  - Existence of bilateral trade agreement between company’s country and the country” sub-criteria are solved with the second type (U type) preference function due to their values and measurement units (i.e., Yes: 1; No: 0). The remaining sub-criteria are measured on a 1 to 9 point scale (i.e., 1: Very Bad; 9: Very Good) and solved with the fifth type (Linear type) preference function.

In order to form an aggregated decision matrix of the market selection problem, geometric means of the scores given by the decision makers were calculated (see Table 3). In this selection problem, all sub-criteria are beneficial criteria where the larger values are always preferred.

Table 3. Aggregated decision matrix of evaluation sub-criteria for eight market alternatives

Sub-criteria	Measurement Unit	Weights	Opt. Dir.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>	A <sub>6</sub>	A <sub>7</sub>	A <sub>8</sub>
FC <sub>1</sub>	1-9 Scale	0.047	□	7.24	8.74	1.41	5.05	1.00	3.16	8.49	6.96
FC <sub>2</sub>	Yes/No	0.013	□	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
FC <sub>3</sub>	1-9 Scale	0.018	□	2.00	6.45	1.68	2.00	1.00	2.63	7.94	3.03
FC <sub>4</sub>	1-9 Scale	0.038	□	6.65	8.21	2.55	5.26	1.00	2.43	7.24	5.57
FC <sub>5</sub>	1-9 Scale	0.023	□	6.24	6.64	3.13	3.87	2.71	5.32	7.74	7.20
FC <sub>6</sub>	1-9 Scale	0.014	□	8.21	8.74	5.48	6.30	3.16	6.73	8.49	7.54
FC <sub>7</sub>	1-9 Scale	0.013	□	7.42	8.49	5.96	6.85	3.13	6.26	8.24	7.42
FC <sub>8</sub>	1-9 Scale	0.014	□	7.20	6.70	3.87	6.73	2.74	5.86	6.96	5.83
EA <sub>1</sub>	1-9 Scale	0.024	□	6.74	5.42	6.09	4.33	4.86	3.83	7.45	2.63
EA <sub>2</sub>	1-9 Scale	0.028	□	5.96	4.86	6.64	5.63	3.87	5.38	4.86	3.60
EA <sub>3</sub>	1-9 Scale	0.059	□	5.73	5.00	1.86	4.05	3.66	3.94	4.23	5.38
EA <sub>4</sub>	1-9 Scale	0.029	□	5.73	5.18	6.29	4.16	4.09	3.66	7.45	3.87
SA <sub>1</sub>	1-9 Scale	0.033	□	6.48	7.24	4.00	7.20	3.56	5.57	7.20	6.70
SA <sub>2</sub>	1-9 Scale	0.067	□	4.56	5.18	2.63	3.72	1.00	4.92	5.96	7.97
ED <sub>1</sub>	1-9 Scale	0.015	□	5.73	5.73	4.05	3.16	2.74	4.68	7.11	6.65
ED <sub>2</sub>	1-9 Scale	0.018	□	5.48	5.96	4.90	4.43	3.08	4.23	5.79	2.99
ED <sub>3</sub>	1-9 Scale	0.024	□	5.18	5.69	2.06	2.91	3.31	3.72	6.44	3.76
ED <sub>4</sub>	1-9 Scale	0.011	□	6.09	6.96	3.60	3.08	4.16	5.60	8.21	4.36
ED <sub>5</sub>	1-9 Scale	0.036	□	7.20	8.24	6.82	6.70	6.48	6.96	7.97	5.96
ED <sub>6</sub>	1-9 Scale	0.036	□	5.73	5.73	6.90	6.90	5.05	5.63	7.42	4.68
ED <sub>7</sub>	Yes/No	0.011	□	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
CA <sub>1</sub>	1-9 Scale	0.239	□	4.53	4.09	2.21	3.08	4.16	2.83	2.51	4.68
CA <sub>2</sub>	1-9 Scale	0.071	□	7.17	4.09	5.96	5.69	3.20	6.70	6.05	4.61
PS <sub>1</sub>	1-9 Scale	0.078	□	7.17	7.14	5.96	4.60	6.30	6.93	7.17	4.12
PS <sub>2</sub>	1-9 Scale	0.042	□	6.96	7.24	5.86	8.74	5.38	2.06	7.97	3.66

After forming the aggregated decision matrix, the steps of PROMETHEE method were followed. The positive ( $\Phi^+$ ) and negative ( $\Phi^-$ ) superiority values of each alternative and ranking results are presented in Table 4. Based on the ranking results, A<sub>1</sub> is the best alternative with maximum  $\Phi_{net}$  value. It is followed by A<sub>2</sub> with the second higher  $\Phi_{net}$  value. On the other hand, A<sub>5</sub> and A<sub>3</sub> ranked eighth and seventh, respectively. The outcomes of proposed model were discussed with the decision makers and they stated that the proposed model can be applied in future to make sound decisions.

Table 4. PROMETHEE superiority values of each alternative and ranking results

Alternatives	$\Phi^+$	$\Phi^-$	$\Phi_{net}$	Ranking
A <sub>1</sub>	0.390	0.045	0.345	1
A <sub>2</sub>	0.330	0.078	0.252	2
A <sub>3</sub>	0.125	0.434	-0.309	7
A <sub>4</sub>	0.152	0.255	-0.103	5
A <sub>5</sub>	0.109	0.423	-0.314	8
A <sub>6</sub>	0.138	0.291	-0.153	6
A <sub>7</sub>	0.358	0.123	0.228	3
A <sub>8</sub>	0.310	0.256	0.054	4

Sensitivity analysis is one of the features provided by PROMETHEE method. The purpose of sensitivity analysis is to determine how changes in criteria weights will change the rank of alternatives (Genc, 2014). The limits on which the weight of each criterion can be changed without changing the exact ranking determined by the PROMETHEE II method are shown in Table 5.

Table 5. The upper and lower limit values of the weights and sensitivities of the sub-criteria

Sub-criteria	Weights	Limit values of the weights		Sensitivities (%)	
		Minimum	Maximum	Decrease	Increase
FC <sub>1</sub>	0.047	0.00	0.28	0.00	460.00
FC <sub>2</sub>	0.013	0.00	0.13	0.00	1200.00
FC <sub>3</sub>	0.018	0.00	0.10	0.00	400.00
FC <sub>4</sub>	0.038	0.01	0.23	75.00	475.00
FC <sub>5</sub>	0.023	0.00	0.09	0.00	350.00
FC <sub>6</sub>	0.014	0.00	0.24	0.00	2300.00
FC <sub>7</sub>	0.013	0.00	0.24	0.00	2300.00
FC <sub>8</sub>	0.014	0.00	0.42	0.00	4100.00
EA <sub>1</sub>	0.024	0.01	0.06	50.00	200.00
EA <sub>2</sub>	0.028	0.02	0.18	33.00	500.00
EA <sub>3</sub>	0.059	0.00	0.06	0.00	0.00
EA <sub>4</sub>	0.029	0.02	0.05	33.00	67.00
SA <sub>1</sub>	0.033	0.00	0.51	0.00	1600.00
SA <sub>2</sub>	0.067	0.05	0.17	29.00	143.00
ED <sub>1</sub>	0.015	0.00	0.08	0.00	700.00
ED <sub>2</sub>	0.018	0.01	0.21	5.00	950.00
ED <sub>3</sub>	0.024	0.00	0.04	0.00	100.00
ED <sub>4</sub>	0.011	0.00	0.06	0.00	500.00
ED <sub>5</sub>	0.036	0.00	0.21	0.00	425.00
ED <sub>6</sub>	0.036	0.02	0.06	5.00	50.00
ED <sub>7</sub>	0.011	0.00	1.00	0.00	9900.00
CA <sub>1</sub>	0.239	0.21	0.24	13.00	0.00

CA <sub>2</sub>	0.071	0.06	0.09	14.00	29.00
PS <sub>1</sub>	0.078	0.00	0.10	0.00	25.00
PS <sub>2</sub>	0.042	0.01	0.13	75.00	25.00

Table 5 shows that the “EA<sub>3</sub> - High profitability of the projects in the country” and “CA<sub>1</sub> - Low level of competition in the country” sub-criteria are sensitive to weight change. In other words, a change to the weight of these sub-criteria may change ranking of the alternatives. It is understood that the rest of them are not very sensitive to weight change and small changes in their weights will not change ranking of the alternatives.

#### 4. Conclusions

The objective of this study is to propose an integrated decision approach for selecting the most appropriate markets. For this purpose, first, an extensive literature review was carried out in order to determine the factors that may affect the selection of a market. After that, an integrated approach was proposed in order to assist the company management in selecting the market. In the proposed approach, AHP is used to find the weights of the criteria and PROMETHEE is employed to determine the complete ranking and perform sensitivity analysis by changing the weights of criteria. The proposed approach is applied to a problem of selecting the most appropriate market in a large scale construction company, which mostly operates in international markets. The final ranking of the market alternatives is obtained with PROMETHEE method as A<sub>1</sub>>A<sub>2</sub>>A<sub>7</sub>>A<sub>8</sub>>A<sub>4</sub>>A<sub>6</sub>>A<sub>3</sub>>A<sub>5</sub>. As the best alternative is A<sub>1</sub>, it is advised to the company management to select for the market. Company management found the results satisfactory and the proposed approach useful. Moreover, they stated that it could be applied in future market selection problems. In future studies, other MADM methods can be used for ranking the alternatives and the obtained results can be compared.

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# Application of Multi-criteria Analysis in the Choice of the Best Option of Sava Program

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## Abstract

Multi-criteria analysis (MCA) is a family of algorithms used to select alternatives according to a set of different criteria and their relative 'weights'. In contrast to Cost Benefit Analysis (CBA), which focuses on a unique criterion (the maximization of social welfare), MCA is a tool for dealing with a set of different objectives that cannot be simply aggregated as in standard CBA. MCA is appropriate for development programs, pursuing simultaneously different policy objectives rather than for the appraisal of a single investment project.

The Program Sava is a complex project including a flood protection component, an energy component, a connectivity and accessibility component, and an urban regeneration component. Due to its technical complexity and its significant environmental, economic and social effects, a multi-criteria analysis was selected as the most appropriate to analyze the merit of the three technical solutions that had been studied during the last years.

The applied methodology was based on the Analytic Hierarchy Process (AHP), the technique that is most commonly used in the world for a choice of options and the multi-criteria analysis process. Under this approach, weights were assigned to objectives. The total score for an option was then defined as the sum of the score for each objective multiplied by its weighting. This method assumes that the contribution of each criterion to the total score is independent on the scores for the other criteria. Finally, an Assessment Summary Table (AST) including 44 indicators of impact was prepared. The selected option was followed by cost and benefit analysis.

*Keywords: evaluation of programs; multi-criteria analysis; analytic hierarchy process*

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## 1. Introduction

The Sava is a tributary of the Danube, flowing through Slovenia, Croatia, along the northern border of Bosnia and Herzegovina, through Serbia, and discharging into the Danube in Belgrade. With a catchment of 97,713 km<sup>2</sup> and length of 990 km, the Sava is the largest tributary of the Danube by volume of water and the second largest by catchment area.

Historically, Zagreb has been developed under Medvednica Mountain and in the last hundred years have seen the city expanding into upper and lower flood plains of the river Sava. Since the huge flooding in 1964 (Figure 1.), Zagreb has developed to the southern bank of the river and protection dykes have been constructed in the narrower city area of Zagreb forming

a river section 100 m wide and about 200 m of flood plain immediately adjacent to the river. During the huge flooding in 1964, high waters broke through dykes and flooded the city causing around 20 victims of drowning and huge material damage.



Figure 1. Flood in Zagreb in 1964 (source: Zagreb 1964)

With financial help from the UN development fund, the preparation of the ‘‘Study for the regulation and utilisation of the river Sava in Yugoslavia’’ commenced and was completed in 1972. This study recommended that flood prevention of the city of Zagreb, Karlovac and Sisak, would best be achieved by the construction of relief canal Sava-Odra-Sava (51 km) which would have the effect of moving the high waters out of the city of Zagreb towards Strelečko on the Sava, near to the city of Sisak. Construction work on the upgrade of the dykes and the construction of the relief canal Sava-Odra took place in the seventies to protect central Zagreb. The planned length of the canal was 51.4km. However, only 33.1 km of the canal was constructed and it currently ends at Odransko field. Therefore flood waters are dissipated into Odransko field, as the canal was never completed to Sisak.

After the construction of the flood protection system of the City of Zagreb, the city rapidly expanded to the south (the area of New Zagreb), and across the river. This has left the river and its flood protection system in the heart of the city which is not desirable. The City of Zagreb and the Zagreb County are facing a series of unresolved problems: the existing system of flood control remains unfinished and its lack of functionality was demonstrated in the flooding of the flood basins in 2010. The availability of water supplies, and issues of wastewater disposal, the deepening and instability of Sava's riverbed, and a reduced supply of drinking water in summer, are mainly consequences of the construction of several hydroelectric power plants along the river Sava in Slovenia.

The construction of a system of regulation and utilisation of the river Sava from the Slovenian border to the city of Sisak would help remedy these problems; it would also provide opportunities for the overall development of region and Republic of Croatia. This was a rationale for development of a program for protection, development and utilization of Sava River and its hinterland from the Slovenian border to Sisak. It is a multi-purpose integrated investment scheme planned to serve multiple functions such as: flood mitigation; the improvement of water management for the supply of drinking water, water for irrigation and industrial needs; hydropower generation; urban regeneration and landscape development; the development of transport; the promotion of tourism; and navigation.

At a time when water services and energy are at the forefront of policy agendas around the world, the ambition of this high-profile Program is to overcome the logic of a stop-gap solution and use the Sava River water resources to combine integrated water management with hydropower utilization. The benefits of the new structures shall foster socio-economic development within a vast area stretching from the Slovenian border to Sisak, comprising of 58 administrative units, 19 cities and 39 municipalities, which are home to 1,327,111 inhabitants (30.9% of total Croatia’s population, according to 2011 Census figures).

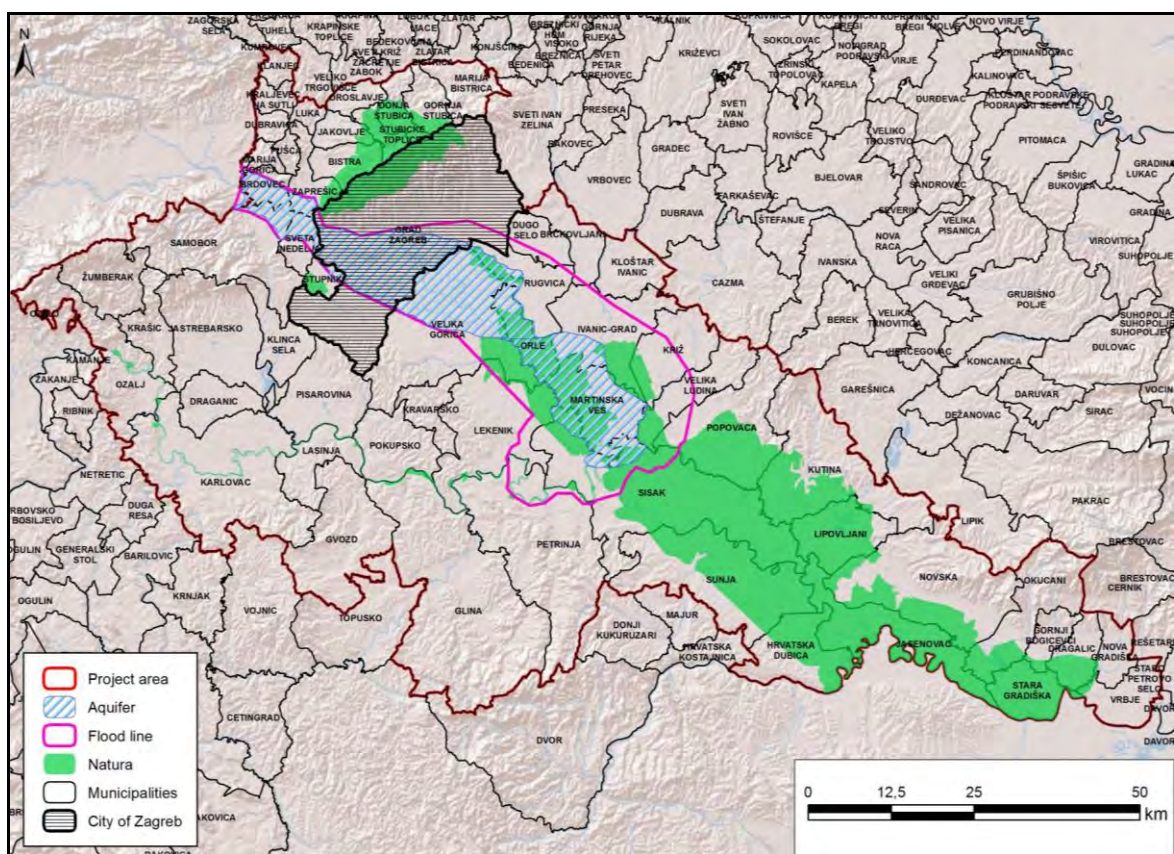


Figure 2. Scope of the Program (source: Feasibility Study 2018)

Hence, the Program is designed as a sustainable investment that addresses these key challenges with a long-term solution which envisages (Figure 2.):

- Construction of 10 hydropower plants in the Sava River,
- Connecting the existing Odra canal with the Sava River into the Sava-Sava Canal

- Reconstruction of the Jankomir spillway,
- Construction of 17 new bridges,
- Reconstruction of 6 bridges on the Odra canal.

The implementation of the Sava Program and its constituent projects will also contribute to the implementation of energy development in Croatia, assisting in the Croatian commitments to reduce emissions of greenhouse gases. Production of electricity from hydropower plants on the Sava River, together with other infrastructure projects in Zagreb (such as gas supply, district heating and cogeneration projects) will increase security of supply for the City of Zagreb and Zagreb County, and in a globalised energy crises will help deliver the basic services to ensure the safety and standards of citizens. The construction of hydropower plants on the Sava River is also necessary to control flows, for stabilisation of the riverbed and the embankments of the river, and will compensate for the effects of the construction of hydropower facilities in the upstream areas of river Sava in Slovenia.

One of the purposes of the Program is to develop the riverside so that the river becomes an integral part of the City of Zagreb, and in order to do that the flood protection system needs to be revised, so that the flood protection margins are recovered for urban development, and the river becomes a feature in the heart of the city. The possibility to eliminate the river flood margins within the City of Zagreb allows for coexistence of the city and the river, and creates preconditions for realisation of the desired concept of “Zagreb on the Sava River”. Moving the hydro technical profile of flood protection of river Sava outside the city and providing drainage of flood waters of Sava through the flood relief channel, frees up space to develop a modern commercial and administrative centre right alongside and on the river.

## **2. The Feasibility Study**

As the first step towards the implementation of the Program, a feasibility study, including technical assessment, financial and economic assessment and a strategic environmental impact assessment were required. The overall objective of the study was to determine if the whole program is feasible and viable, or which projects within the program are feasible and viable and then to elaborate project documentation to the extent that is required to facilitate the loan engagement process to the satisfaction of the international financing institutions, including the European Commission with respect to EU Funds.

The Program has been under the authority of the Ministry of Environmental Protection and Energy which chairs the Steering Committee, a body responsible for strategic decisions regarding the Program. Its Members are representatives from line Ministries, City of Zagreb, Zagreb County, Sisak-Moslavina County, Hrvatska Elektroprivreda (HEP) d.d., Croatian Waters, and the Center for Monitoring Business Activities in the Energy Sector and Investments (CEI). The study preparation activities have been coordinated by the Program’s team employed by Program Sava Co.Ltd., a special purpose company to perform the Program Management Unit tasks for both the implementation and the operation phases. This company has been assisted by the Expert Council<sup>23</sup>, an independent discussion and monitoring panel

<sup>23</sup> The authors are members of the Expert Council

formed by 26 recognized experts in the fields covered by the Program, established to assess key Program deliverables. The total estimated investment in the Program is €1.4 billion without contingencies.

A grant award of €1,500,000 towards the total feasibility study budget of €2,000,000 was approved by the Western Balkans Investment Framework (IPA WBIF Infrastructure Project Facility Technical Assistance 3) Steering Committee in December 2012, with the difference of €500,000 to be contributed by national co-financing. The feasibility study was prepared by the Mott MacDonald, Atkins and WYG consultants, as WBIF-IPF3 consortium members, using a range of local subcontractors. The terms of reference provide for a two-stage development of the feasibility study. The first stage comprised an option study to determine the preferred option for further study under the second stage. The second stage envisages the completion of the feasibility study and the parallel preparation of a strategic environmental assessment report, the latter providing inputs for the feasibility analysis.

The feasibility study began by defining and investigating three options for the Program (Hydropower 2014):

“Option 0 (Base Option) is not a complete flood protection scheme and excludes hydropower development. It consists of separate projects to be prepared and implemented by Croatian Waters. This option includes: completion of embankments upstream of Zagreb; construction of weirs along the Sava to stabilise the river bed; lowering the spillway at the junction of the Sava and the Sava-Odra canal and deepening of the canal further downstream; re-profiling of the Sava-Odra canal and its dykes; flood control structures including perimeter dykes around Lonjsko and Odransko retention basins, a transversal dyke crossing Odransko polje, and a floodgate at Palanjek spillway to improve flood control into Lonjsko polje; and bridge and road reconstruction.

Option 1 consists of five HPPs; re-profiling of the Sava-Odra canal and its embankments to provide increased flow capacity; extension of the existing Sava-Odra canal by 5km to join the Sava River; embankments retaining the reservoir for HPP Podsused will also provide improved flood protection upstream of Zagreb; flood control structures including perimeter dykes around Lonjsko and Odransko retention basins, and a floodgate at Palanjek spillway to improve flood control into Lonjsko polje; a ship lock included within HPP Strelečko; and bridge and road reconstruction.

Option 2 consists of seven hydropower plants, of which four are small hydro plants; construction of a new floodgate to replace the Jankomir spillway; re-profiling of the Sava-Odra canal and its dykes to provide increased flow capacity; extension of the existing Sava-Odra canal by 5 km to re-join the river Sava; dykes retaining the reservoir for HPP Podsused will also provide improved flood protection upstream of Zagreb; flood control structures including a floodgate at Palanjek spillway to improve flood control into Lonjsko polje; a ship lock included within HPP Sisak; and bridge and road reconstruction.”

### 3. Multi-Criteria Analysis

European Commission Guide to Cost-Benefit Analysis of Investment Projects (EC 2015) recommends:

“Multi-criteria analysis (MCA) is a family of algorithms used to select alternatives according to a set of different criteria and their relative ‘weights’. In contrast to Cost Benefit Analysis (CBA), which focuses on a unique criterion (the maximisation of social welfare), MCA is a tool for dealing with a set of different objectives that cannot be aggregated through shadow prices and welfare weights, as in standard CBA. MCA is appropriate for development programmes, pursuing simultaneously different policy objectives (e.g. equity, environmental sustainability, improved quality of life, etc.), rather than for the appraisal of a single investment project.”

More specifically regarding the flood management *The EIB Guide for Preparation for Flood Risk Management Schemes* (EIB 2007) states:

”CBA is probably the most common appraisal method for flood risk management. It is rigorous and capable of producing unambiguous results to guide decision makers. On the other hand, by reducing complex considerations to a single criterion, by its stress on quantification, and by leaving out of account factors that cannot be quantified, it may be considered to be too one-dimensional.

Multi-criteria analysis (MCA) is increasingly being used in the assessment of FRM (Flood Risk Management) projects, in preference to the sole reliance on single-criterion methods such as CBA. MCA permits the involvement of a wide range of stakeholders, and offers greater transparency to the decision-making process. It is also less “technocratic” than CBA, and is arguably more suitable where the effects of a scheme are non-quantifiable or intangible. In the experience of many practitioners, the main advantage of MCA is in the process rather than the product: the act of bringing different stakeholders together to focus on a common problem is more fruitful than any formal, numerical results that may be produced.

The simplest form of MCA is to break down the appraisal into different subject areas (hydrological, economic, social, environment, financial etc.) and to present the results of each analysis separately to the decision-maker (or committee) to take a subjective, or democratic, judgement. Although this procedure is highly judgemental, it avoids specialist analysts becoming involved in political, social, moral or other issues on which they have no standing.”

The most commonly known methods that can be used for MCA are:

- ELECTRE,
- AHP,
- PROMETHEE, and
- TOPSIS.

ELECTRE method was conceived by Bernard Roy (Roy 1991). It has evolved through a number of versions, i.e. I through IV; all versions are based on the same fundamental conceptions but are operationally rather different. Unlike other methods, the ELECTRE

method has ability to incorporate the fuzzy nature of decision making by using thresholds of indifference and preference.

Analytic Hierarchy Process (AHP) was introduced by Thomas L. Saaty (Saaty 1980) with the intention of optimizing decision making when one is faced with a mix of quantitative, qualitative, and sometimes incompatible factors that are taken into consideration. This technique offers a way of breaking down the overall method into a hierarchy of sub-problems, which are easier to estimate. AHP has been recognized for making very effective and complicated, often irrevocable decisions.

The Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) was conceived by Jean-Pierre Brans and Ph. Vincke in 1984 (Brans and Vincke 1984). It provides the decision maker with both partial (PROMETHEE I) and complete (PROMETHEE II) rankings of the actions. It has advantages when significant elements of the decision are difficult to quantify or compare, or where cooperation among team members are constrained by their diverse specializations or viewpoints.

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a [multi-criteria decision analysis](#) method, which was originally developed by Ching-Lai Hwang and K. Paul Yoon in 1981 (Hwang and Yoon 1981). It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. An assumption of TOPSIS is that the criteria are [monotonically](#) increasing or decreasing.

The MCA method accepted by the Expert Council for the choice of the best option was based on the Analytic Hierarchy Process (AHP) technique. Under this approach, weights are assigned to objectives. The total score for an option is then defined as the sum of the score for each objective (also defined as criterion) multiplied by its weighting. This method assumes that the contribution of each criterion to the total score is independent on the scores for the other criteria.

#### **4. The Process of Analytic Hierarchy Process**

The steps in the AHP process of comparison among the options of the Sava Program were the following ones (Conceptual Solution 2014):

- Establish the Program objectives and purpose of objectives whenever appropriate.
- Identify and define the options.
- Identify the criteria linked to the objectives for options comparison.
- Identify the impacts and indicators that will be used to assess the consequences of each option.
- Describe/quantify the expected performance of each option against the criteria (objectives-purposes of objectives-impacts-indicators).
- Assign weights for each of the objectives to reflect their relative importance to the decision.
- Score the options, i.e. assess the value associated with the consequences of each option.



- Combine the weights and scores for each of the options to derive an overall value (for each of the options).
- Examine the results.
- In case the difference in scoring between two options, or the three options, is not significant, conduct a sensitivity analysis.
- Prepare an option appraisal report.

The process has been designed to ensure that the assessment of options is evidence-based, transparent and established on comprehensive expertise. The entire process, facilitated by the Expert Council, was paperless. In line with the terms of reference for the appraisal of the solutions, a number of objectives covering technical, environmental, economic, financial and social aspects were developed and agreed by the Expert Council, upon which the evaluation criteria shall be established, including (Study Proposal 2013):

1. An adequate hydro-technical solution that achieves a flood control of areas along the river from the border with Slovenia to Sisak, the level of safety being equal to or greater than the existing water management solutions.
2. Securing the long-term water supply requirements of Zagreb and Velika Gorica by increasing the capacities and quality of drinking water.
3. Enabling the navigability of the river Sava to Prevlaka and beyond by the drainage canal Sava - Sava to Velika Gorica. The class of the waterway from Sisak to Velika Gorica should be equal to the class of the waterway to Sisak.
4. Utilise hydropower potential of the river Sava from the border with Slovenia to Sisak, including the definition of the regime at the Slovenian-Croatian border, taking into consideration current and future hydropower development on the Sava River in Slovenia and Croatia.
5. Use hydropower potential of Medvednica.
6. Development of project area with all zoning, transportation and tourist / recreational facilities along the river and on the river Sava.
7. Releasing the existing urban corridor of the river Sava which is now reserved for the high waters, and which allows the “Zagreb on Sava” concept.
8. Developing modern agriculture with irrigation and drainage in this area.
9. Maintain or improve water management regime in retention areas.
10. Maintain existing hydrological regime beyond Sisak.
11. Protection of the environment.
12. Social effects.
13. Financial results and economic benefits.
14. Adaptability to climate change.

The option assessment process started with preliminary evaluation of a long list of impacts and measures under an impact Appraisal Summary Table – AST (Table 1.) to filter out any that are not applicable or could be redundant. The AST started by being completed by the Expert Council, on the basis of the Program objectives. Under this step, columns 1-2-3-4 were completed. The indicators included all aspects of the decision problem, i.e. all the objectives, with care to avoid redundancies.

Each option was then analyzed taking into account the established technical, economic, financial, environmental and social criteria. Consequently, experts from the Consultant completed columns 6-7-8. The AST cover all the options, even if the form shows nil for some of the criteria under some of the options. Column 5 – existing situation, was filled in if and when needed. The AST presents the criteria, the selected impact indicators, and the performance of each of the three options for each impact indicator, as assessed by the team of consultants. Included in the AST were a number of items (e.g. hydro power stations, exploitation of mineral resources) that required financial (as distinct from economic) evaluation because they will generate considerable revenues.

1	2	3	4	5	6	7	8
Objectives (Criteria)	Purpose of objectives	Impact(s) (same for all options)	Indicator(s) (Measure(s))	Existing Situation	Option 0	Option 1	Option 2
					Quantity or Description	Quantity or Description	Quantity of Description
1. Flood control							
2. Water supply							
3. Navigability							
4. Hydropower potential							
...							
14. Climate change							

Table 1. The template of the Appraisal Summary Table – AST (source: Conceptual Solution 2014)

Once the AST was completed, all the criteria that eventually result in the same quantified impact under all the three options considered, were removed from the list. Then the analysis continued with the following step i.e. establishment of an appropriate scoring system (Table 2.). A Scoring Guidance document was also prepared to provide the background for the scoring exercise. This document provides relevant definitions and explains the scoring system for each impact indicator.

Criterion	Purpose of Objectives	Impacts	Indicators of Impacts	Scoring System
2. Securing the long-term water supply requirements of Zagreb and Velika Gorica by increasing the capacities and quality of drinking water.	Secure drinking water capacity and quality in the project area.	4. Increase/ Decrease of low, medium and high groundwater levels for each well field i.e. pumping site for abstraction of drinking water (Active, Inactive/Backup, Inactive/Abandoned, Planned in Spatial Plan).	4. Low, medium and high groundwater level higher or lower than ones for existing state [m].	Q
		5. Potential contamination of wells/well fields from known sources of pollution.	5. Percentage of potentially contaminated wells on each well field i.e. total capacity on each well field potentially endangered [l/s].	Q

		6. Gain/Loss of valuable aquifer areas for development of well fields with respect to potential contamination from known sources of pollution.	6. Square kilometres of valuable aquifer areas gained/lost [km <sup>2</sup> ].	Q
		7. Stopping of negative trends of groundwater level.	7. Change of the character of the groundwater level trend [% of negative trend stopped].	Q
		8. Stabilization of groundwater flow directions.	8. Maximum degree of change of groundwater flow direction within Wellfield catchment area [°].	Q

Table 2. An example of scoring system – Objective 2 (source: Conceptual Solution 2014)

Qualitative scoring systems was also established in order to allow for scoring whenever a quantity cannot be calculated for one or more indicators.

Criteria /Objectives	Indicators of Impact	Scoring system type	Range	Options Scoring / Quantities		
				Option 0	Option 1	Option 2
WATER SUPPLY <b>Objective 2.</b> Securing the long-term water supply requirements of Zagreb and Velika Gorica by increasing the capacities and quality of drinking water.	2. Low, medium and high groundwater level higher or lower than ones for existing state [m].	Q	0 +10	2.10	10	5
				0.7	3.5	1.8
	3. Percentage of potentially contaminated wells on each well field i.e. total capacity on each well field potentially endangered [l/s].	Q	0 +10	7.20	9.30	10
				5780	3510	2700
	4. Square kilometers of valuable aquifer areas gained/lost [km <sup>2</sup> ].	Q	-10 +10	-0.90	9.60	10
				-1	11	12
	5. Change of the character of the groundwater level trend [% of negative trend stopped].	Q	0 +10	10	10	10
				100	100	100
	6. Maximum degree of change of groundwater flow direction within Wellfield catchment area [°].	Q	0 +10	7.60	10	10
				47	5	5

Table 3. An example of Assessment Summary Table – Objective 2. (source: Conceptual Solution 2014)

Under the next step, each criterion was weighted by the Expert Council members, irrespective on the number of indicators foreseen under each objective (Table 3.). Weighting of criteria was based on the pairwise method. The design of this approach was aimed at ensuring that the weights will respect the relative magnitude of the differences in importance which the experts place on one type of impact versus another. For 14 objectives there were all together 78 pairs compared to each other.

1. *4												
	0	1	2	3	4	5	6	7	8	9	10	
1. Flood Protection	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	2. Water Supply
2. *8												
	0	1	2	3	4	5	6	7	8	9	10	
1. Flood Protection	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	3. Navigability
3. *4												
	0	1	2	3	4	5	6	7	8	9	10	
1. Flood Protection	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	4. Hydropower

Table 4. Examples of pairwise comparison (source: Conceptual Solution 2014)

When comparing criteria, a scale of importance ranged from 0 points for no importance at all up to 10 points for highest importance (Table 4.). The selected preferred points were inserted only for the criterion on the left. For example, if an expert considers that the criterion on the left is more important than the criterion on the right, he/she can assign to it 7 points and the system automatically assigns the difference of 3 points to the criterion on the right. If the expert considers that the criterion on the left is less important than the criterion on the right, he/she can assign to it 2 points and the system automatically assigns the difference of 8 points to the criterion on the right.

Results of weighting and scoring were aggregated through weighted summation, where weights and scores for each option and criterion were multiplied and total weighted scores were then added to compare the options. Underlying this approach (a simple linear additive model) is the assumption that the criteria are mutually preference independent.

The final output was the Overall Objectives Weighting Sheet (Table 5.) that assigns weighting to each objectives/criterion (the same for each option). All the outcomes and results of the process were adequately recorded.

Criterion	Scores	Weight
2. Water supply	1539.00	10.96%
1. Flood protection	1299.00	9.25%
10. Environment	1206.00	8.59%
4. Hydropower	1152.00	8.21%
9. Downstream effects	1117.00	7.96%
7. Urban Regeneration	1087.00	7.74%
8. Agriculture	1060.00	7.55%
12. Financial results	1040.00	7.41%
11. Social inclusion	1011.00	7.20%
5. Transportation	968.00	6.89%
13. Climate change	888.00	6.32%
6. Tourism and Recreational Facilities	861.00	6.13%
3. Navigability	812.00	5.78%

Table 5. The Overall Objectives Weighting Sheet (source: Conceptual Solution 2014)

During the so called “MCA workshop”, each expert scored individually each of the three options, for each criterion and for each AST indicator, according to a -10 +10 scale, with 0 as no change from existing situation. In case no quantification is included for a given indicator of impact, the experts were able to express their score by using the agreed scoring system (based on qualitative assessment). The scoring system based on answers such as Yes/No or qualitative assessment, were considered as a residual one, applicable only when a quantitative measurement was not available.

As a result, an Individual Scoring Table was filled in by each expert. The results were presented in real-time during the workshop. In this way each workshop participant was able to check the deviation between the average score and the score he/she has assigned to a particular criterion/indicator. Subsequently, the deviations between the scores assigned by each expert was presented to the Expert Council. In case deviations are higher than  $\pm 10\%$  (consistency condition), the scores were discussed by the experts and the process was repeated until all scores complied with the consistency condition.

The weighting, scoring and weighted summation process were managed through dedicated software applications accessible from the web, developed under the project based on standard statistical software applications.

Under the final steps, the weights and scores were combined for each of the options to derive an overall value for each of the three options. A total MCA score was calculated for each option as the sum of the weighted scores across the objectives/criteria. The final MCA score was intended to reflect the performance of each option in terms of the Program’s objectives. The results were presented in the Options Ranking Table (Table 6.).

Criteria	Weights	Option 0	Option 1	Option 2
1. Flood protection	0,09	0,49	0,68	0,93
2. Water supply	0,11	0,57	0,96	1,10
3. Navigability	0,06	0,00	0,58	0,58
4. Hydropower	0,08	0,00	0,82	0,76
5. Transportation	0,07	0,26	0,57	0,67
6. Tourism and Recreational Facilities	0,06	0,00	0,61	0,61
7. Urban Regeneration	0,08	0,19	0,00	0,77
8. Agriculture	0,08	0,61	0,75	0,72
9. Downstream effects	0,08	-0,32	-0,13	-0,27
10. Environment	0,09	0,00	-0,61	-0,27
11. Social inclusion	0,07	-0,11	-0,01	0,16
12. Financial results	0,07	0,00	0,46	0,74
13. Climate change	0,06	0,49	0,41	0,60
Score		2,189602	5,098182	7,100371
Final weighted score		218,96	509,818	710,037

Table 6. The Options Ranking Table (source: Conceptual Solution 2014)

Following the standard methodology in this respect, it was studied how much the weights of criteria had to change in order for the ranking of options to change. In the end the sensitivity coefficients were computed. From this analysis it was concluded that important changes should appear in the weights of some criteria in order for the ranking of options to change. Therefore, the analysis run is robust and results are statistically significant.

## 5. Conclusions

Amongst the options assessed in the MCA process, Option 2 was considered to be of higher priority by the Experts Council, who recommended Option 2 for further feasibility analyses. Option 2 is a multi-purpose regulation and development option aiming to improve the regulation of the Sava River so it can be developed for a wide range of purposes and benefits. The experts also concluded:

- Option 2 is the highest priority option for flood control;
- Option 1, generating 699 GWh/year, would be the priority option for power generation, compared to Option 2, generating 644 GWh/year;
- Option 2 is the highest priority option for water supply;
- Option 2 is the highest priority option for urban regeneration; and
- Options 1 and 2, are of equal priority for transport and navigation.

The choice of the best Sava Program option was made using the AHP method. The options were compared against 14 criteria. Taking into account the importance and scope of the program, the number of experts participating as well as the number of applied criteria, this was the most complex application of multi-criteria analysis in Croatia so far. Such a complex analysis could not have been carried out without a good preparation and use of the appropriate software tools.

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# Economic Effectiveness of Large-scale Infrastructure Projects within the Reference Period Length Context

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## Abstract:

Positive evaluation of economic effectiveness of large-scale transport infrastructure projects represents one of the essential criteria for the provision of funds for their construction, reconstruction or modernization. The economic evaluation is based on monitoring the differential financial and economic cash flows between the zero and the design variant of the project investment plan within a defined reference period of 30 years. CFs consist of investment costs, operating income, operating expenses, societal benefits and harm, as well as the residual value of the investment. This occurs in non-zero values during the last year of the project reference period, unless the economic service life of the infrastructure being constructed, is exhausted. On a sample of 9 investment plans of projects submitted to the State Fund for Transport Infrastructure of the Czech Republic for financing in the 2017 – 2019 period, the authors of the article have monitored to what extent the project effectiveness has been affected by the residual value and how long period has been in fact evaluated in the project. The evaluated sample data suggests that the discounted residual value share on the total discounted societal project benefits represents 15% – 40%, which is naturally subsequently reflected in the ENPV. The authors of the article conclude that project evaluation, which actually extends to the average economic service life of the infrastructure being built due to including the residual cost, appears to be justified since these projects, while properly repaired and maintained, show their planned utility until the end of their service life.

*Keywords:* large-scale transport investment project; residual value; reference period; CBA; economic effectiveness

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## 1. Introduction

Large-scale infrastructure projects are publicly funded projects using different financial mechanisms. According to Czech public finance legislation (Act on Financial Control, 2001), an essential aspect of spending public funds is compliance with the 3E (Economy, Effectiveness, Efficiency) principle, which must be achieved at all stages of their life cycle. In the pre-investment phase, the evaluation of transport infrastructure projects focuses mainly on their effectiveness, which is examined using CBA and, in cases where this method cannot be used, a multi-criteria analysis has proven effective. In the investment phase, emphasis is placed on the efficient and economical procurement process and the selection of an economically advantageous infrastructure contractor and subsequent monitoring of the construction during its implementation phase (quality, costs and time). In the operational phase, it is an efficient operation of the construction by its own or hired facility manager and once more monitoring the operation from the perspective of the public sector.

The article is focused on the pre-investment phase, specifically on the analysis of large-scale transport infrastructure projects, which were evaluated on the basis of CBA in the pre-investment phase according to Czech methodological procedures. The CBA examines the financial sustainability and economic efficiency of the projects based on the modelling of their financial and economic Cash Flow (CF) and the subsequent calculation of Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit Cost ratio (B/C) economic efficiency indicators. Due to the public character of the projects, the economic efficiency is demonstrated by an economic analysis, into which the following CFs enter:

- economic investment costs, it is the adjustment of financial investment costs by fiscal corrections, in particular by applying the conversion factors defined in the methodology,
- economic operating income, e.g. toll
- project economic operating costs, such as repair and maintenance, labour and energy costs,
- societal benefits / harm, such as reduced travel time, reduced accidents, noise, air pollution and climate change slowdown,
- residual value.

The effects and proportions of individual societal benefits on the overall effectiveness of the projects in relation to their investment and operating costs were addressed in the previous studies, where the significant impact of travel time savings on transport infrastructure project users was demonstrated in a long-term perspective (Börjesson et al, 2011; Salling and Leleur, 2015). The Czech study confirmed the results of international studies which brought also the conclusions that travel time savings represent the most important part of total benefits and represent between 50 – 80% of total benefits. Others benefits demonstrated fundamentally less significant shares (Korytářová and Papežiková, 2015). These analyses dealt with the factual content of the individual variables of the costing formula, in detail the number of the units of measure and the price per unit of measure of each partial variable.

The last item in the CF formula is the residual value. This reflects the residual potential of the fixed assets whose economic service life has not been yet fully depleted. Pursuant to the Article 18 (Residual value of investment) of the Commission Delegated Regulation (EU) No. 480/2014, the assets of an operation have design service life in excess of the reference period referred, their residual value shall be determined by computing the net present value of cash flows in the remaining life years of the operation. This is how also the Czech methodology of its determination has been built, with similar costing also works Maravas and Pantouvakis, 2018. It is therefore a modelling of the material content of the calculation formula until the end of the service life of the acquired assets.

In the field of the expert evaluation of the large-scale transport infrastructure projects, a research question has arisen as to how long the actual project period under evaluation is, and to what extent the residual value, i.e. the model performance of the projects after the end of the reference period contributes to the effectiveness of the projects. The Czech Methodological Procedure (Departmental Methodology, 2018) requires a 30-year (reference) period for



transport infrastructure projects. The basic financial and economic CF is modelled for this period. The overall service life of transport infrastructure constructions, consisting of a number of construction buildings, shows a significantly longer service life. It is determined on the basis of the weighted arithmetic average of the economic service life of the individual constructions (e.g. wearing layer, bedding layer, substructure, utilities and communications, drainage equipment, ground body, bridges, tunnels) and their construction costs, where the weights are the total construction costs of the construction being researched.

## 2. Materials and Methods

The research sample consisted of 9 investment projects of plans/variants of motorway and main road construction projects in the Czech Republic; whose feasibility studies were prepared in the 2017 – 2019 period. The economic evaluation of the projects was based on the Departmental Methodology 2018 based on the European recommendations for the 2014-2020 programming period (CBA Guide, 2014). The economic effectiveness of each investment project is determined on the basis of differential CFs between the zero option (variant without a project) and the investment option (variant with a project) according to the calculation formula. The 30-year evaluation period includes both the construction and operation phases. Discounted economic CFs are determined using a 5% discount rate. As a part of the analysis, all project revenues and expenditures were converted to EUR at a uniform rate of CZK 25.66 / EUR (Czech National Bank, CNB, 6. 6. 2019).

The following Table 1 shows the list of analysed investment projects with their basic economic characteristics.

Tab. 1 Economic characteristics of the researched projects  
(authors' own processing according to project feasibility studies)

Investment Project	DTB (mil. EUR)	DTC (mil. EUR)	ENPV (mil. EUR)	ERR
I/36 Pardubice	241	51	190	19.20%
I/13 Krásná Studánka – Dětrichov	75	60	15	6.48%
I/4 Nová Hospoda – Stráž	162	107	32	6.85%
D35 Opatovice – Mohelnice	5,266	1,520	3,746	16.10%
I/44 Zábřeh – bypass	163	126	37	6.70%
D3 Třebonín – Dolní Dvořiště, state border	773	374	399	10.01%
I/33 Náchod – bypass	230	158	72	7.55%
I/20 Pištín – České Vrbné	156	69	86	12.40%
I/38 MÚK Jihlava south – Stonařov	111	101	10	5.65%

Where:

- DTB ... Discounted Total Benefits,
- DTC... Discounted Total Costs,
- ENPV... Economic Net Present Value,

- ERR... Economic Internal Rate of Return

Tab. 2 contains information concerning the length of the investment and operational phases of individual projects within the methodology of the required evaluated 30-year period, the service life of individual projects and the total discounted value of the residual investment value, which is added as a positive CF to the last year of the investment evaluation of the project according to the required methodological procedures.

Tab.2 Total project service life and discounted investment residual value

(authors' own processing according to project feasibility studies)

Investment Project	IPh (years)	OPh (years)	TL (years)	RL (years)	DRV (mil. EUR)
I/36 Pardubice	3	27	57	30	65
I/13 Krásná Studánka – Dětrichov	3	27	58	31	19
I/4 Nová Hospoda – Stráž	6	24	50	26	30
D35 Opatovice – Mohelnice	15	15	61	31	1,922
I/44 Zábřeh – bypass	7	23	54	31	24
D3 Třebonín – Dolní Dvořiště, state border	3	27	59	32	234
I/33 Náchod – bypass	3	27	59	32	64
I/20 Pištín – České Vrbné	4	26	44	18	31
I/38 MÚK Jihlava south – Stonařov	3	27	58	31	27

Where:

- IPh ... Investment Phase (Construction);
- OPh ... Operational Phase;
- TL ... Total Lifetime;
- RL ... Residual Lifetime;
- DRV... Discounted Residual Value

### 3. Results and Conclusions

Data in Tables 1 and 2 shows that the discounted residual value of all the projects under research has a significant share on the overall project benefits, ranging from 15% – 42% with the mean value given by the arithmetic mean of 29%, see Tab. 3.

Tab. 3 Share of discounted residual value on the total discounted project benefits

(authors' own processing)

Investment Project	DTB (mil. EUR)	DRV (mil. EUR)	Share of DRV on DTB
I/36 Pardubice	241	65	27%
I/13 Krásná Studánka – Dětrichov	75	19	25%
I/4 Nová Hospoda – Stráž	162	30	18%
D35 Opatovice – Mohelnice	5,266	1,922	36%

I/44 Zábřeh – bypass	163	24	15%
D3 Třebonín – Dolní Dvořiště, state border	773	234	30%
I/33 Náchod – bypass	230	64	28%
I/20 Pištín – České Vrbné	156	31	20%
I/38 MÚK Jihlava south – Stonařov	111	27	25%

The reduced value of project benefits (i.e. modelled as Discounted Residual Value (DRV) = 0) causes significant shifts in the perception of project effectiveness within the evaluated period. The values of ENPV without RV and relative model decrease of the effectiveness indicator value are shown in Tab. 4.

Tab. 4 Effect of the project residual value on the ENPV efficiency indicator  
(authors' own processing)

Investment Project	ENPV (mil. EUR)	ENPV DRV (mil. EUR)	without (mil. in ENPV	Decrease in ENPV
I/36 Pardubice	190	125		34%
I/13 Krásná Studánka – Dětrichov	15	-4		125%
I/4 Nová Hospoda – Stráž	32	25		21%
D35 Opatovice – Mohelnice	3,746	1,824		51%
I/44 Zábřeh – bypass	37	13		65%
D3 Třebonín – Dolní Dvořiště, state border	399	140		65%
I/33 Náchod – bypass	72	9		88%
I/20 Pištín – České Vrbné	86	57		34%
I/38 MÚK Jihlava south – Stonařov	10	-17		267%

It concludes from the above mentioned facts that the discounted residual value has a significant share on the effectiveness of the project and the project evaluation has a different final length of the evaluated period, i.e. the 30-year construction and operation period prescribed by the methodology and the residual service life according to the individual buildings that the construction contains. The inclusion of this performance in the economic effectiveness seems to be justified since with proper repair and maintenance of a newly constructed, reconstructed or modernised transport infrastructure, these projects will show their planned utility based on the modelling of input variables until the end of their service life. Table 4 clearly shows that if this residual performance is not taken into account, especially in relatively smaller projects, the ENPV would fall below the effective limit ( $ENPV < 0$ ) and could not be realized in this respect, which would not be correct in terms of their actual benefits.

The article presents an original evaluation of the effect of including the residual value of an investment into the evaluation of the economic effectiveness of the transport infrastructure projects. Subsequent research could focus on a broader research sample and comparison of the

existing data with other methodological processes to determine the residual value of the investment.

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# The Influence of National Cultures on Organizational Culture in Construction

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## **Abstract:**

According to Brown (1995), there are three main sources of organizational culture – national culture, type of economic activity and founder or dominant leader inside an organization. This article analyzes interaction between first two factors. More precisely, this article examines the influence of national culture of organizational culture in construction. The main questions are, first: is there any national culture which is optimal for organizational culture in construction? Second, is it possible to identify elements of national cultures that are detrimental for organizational culture in construction and, accordingly, to change them in order to improve organizational culture? In addition, this article tries to predict the future of organizational culture in construction. Will globalization annihilate national differences in organizational culture in construction or we may expect competition between different organizational cultures based on differences between national cultures? Based on literature review, the following hypotheses are formulated: since construction business demands relatively high level of discipline, national cultures that are relatively authoritarian and collectivistic are sources for unqualified workers in construction. This is one of the reasons why construction business relatively easily absorbs immigrants. However, western culture (especially American organizational culture) spreads through the process of globalization. Accordingly, it can be expected that, at the top level of management, differences of national culture will have diminishing influence.

*Keywords: organizational culture, national culture, construction, globalization, management*

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## **1. Introduction**

According to Brown (1995), there are three main sources of organizational culture – national culture, type of economic activity and founder or dominant leader inside an organization. This article analyzes interaction between first two factors. In order to do it, it is essential to define, first, the main terms. According to The Business Dictionary, national culture is “the set of norms, behaviors, beliefs and customs that exist within the population of a sovereign nation.” Accordingly, international companies develop management and other practices in accordance with the national culture they are operating in. However, inside the same national culture, companies have different organizational culture, because this culture is influenced by the type of activity (Brown 1995, see above)

There are numerous definitions of organizational culture. It is out of the scope of this article to present them. Therefore, only the definition used in this article is presented. According to Jones (2004, 195). Organizational culture is “the set of shared values and norms that controls

organizational members' interactions with each other and with people outside the organization.”

It is obvious that definitions of national culture and organizational culture are very similar, and this is not by chance. The very concept of “culture” was first developed inside anthropology. Later, this concept was applied in sociology and, finally, in organizational science and management (see Janićijević, 2013: 541).

So, which influence has national culture on organizational culture? The origin of this type of analysis can be found in the work of Max Weber, especially in his book *Die Protestantische Ethik, Und der Geist des Kapitalismus* (1905). Weber argues that nations in which Protestants are majority are the most developed ones because value system in these countries is favorable for economic development. Using modern terminology, appropriate national culture has positive influence of organizational culture and economic activities. However, even this pioneering work showed all difficulties in analyses of national cultures. To illustrate, Weber (1905) argued that Confucianism lacks the main values which are the preconditions for fast economic development – harmony, decency, virtue, pacifism, frugality... Yet, countries with Confucian values (China, Taiwan, Hong Kong, Singapore) have been the most successful ones in promoting economic development during the last seventy years. In other words, Weber's theory shows that analyses of national cultures are easily influenced by prejudices and stereotypes.

Nevertheless, during the last forty years, very important works have been published about the influence of national cultures on organizational cultures, especially works by Geert Hofstede. In his main book, *Culture's Consequences* (2001), he compares functioning of IBM branches in forty countries around the world. Analyzing the same company in different national settings, Hofstede isolated the independent variable (national culture) and examined the influence of this variable on organizational culture. His book is still the seminal book for research in the field of Cross-Cultural Management and this book incited plethora of analyses about the influence of national culture on organizational culture. For this article, it is important to mention work by Andre Laurent (1983) and his study of inclination toward authoritarianism in different national cultures. He found huge differences among nations in this field. To illustrate, just 10 percent of respondent in Sweden answered positively on statement “it is important for the manager to have precise answers to any question that his or her subordinate can ask about the job.” In contrast, 78 percent of respondents in Japan support this statement. It can be concluded that in Japan people tend to respect authority of their superiors much more readily than in Sweden. Furthermore, subordinate in Japan expect from superior to solve problems and this fact leaves less initiative for subordinate workers. Economic success of Japan shows that this level of respect is not necessarily bad for working performances, especially not in branches of economies that demand a high level of discipline. However, it is very likely that occupations that demand innovative approach can more easily flourish inside Swedes type of national culture. We will return to this question in the next section, which explores organizational culture in construction business.

To return to Hofstede (2001) once again, his differentiation between national cultures is based on six equally important dimensions. For this article, the most important is differentiation

between cultures with low distance of power from those with high distance. In later, those who have power are considered as special type of people. Subordinate people have almost unlimited trust in ability of powerful people. In contrast, cultures with low distance of power tend to challenge the authority. Respect of those in power is not unconditional. Furthermore, this type of societies tends to be more egalitarian than societies with high distance of power. Hofstede developed instruments (questionnaires for surveys) for measuring distance of power in different national cultures (index of distance of power). Differences among national cultures, based on this index, are huge. To illustrate, Austria has index 11, Israel (13) and Denmark (18). On the other side of the spectrum are Mexico (81), Philippines (94), Panama and Guatemala (95) and Malesia (104). Obviously, countries with huge power distance are clustered in Latin America and Asia.

Is huge power distance good or bad for business? Do national cultures with low power distances have more appropriate organizational cultures? Apparently, it is not possible to find a general answer on this question. On one hand, Asian cultures, with high power distance, have had amazing success in promotion of economic growth after the World War II. On the other hand, Latin American countries, which also have national cultures with huge power distance, have been much less successful in promotion of economic growth (see Maddison Project Database, 2018). A much better question is the following: for which sort of business power distance is beneficial and for which ones it is not?

Since this article focus on relationship between national cultures and organizational culture in construction, the next section examines organizational culture in construction business.

## **2. Organizational culture in construction**

There are numerous articles about organizational culture in construction business. It would be out of the scope of this article to present all the elements of this culture. Therefore, this article will focus on one important element – level of authoritarianism in organizational culture in construction. In other words, this article tries to connect Hofstede's analysis of national cultures with researches about organizational culture and, then, implements this analysis on the analysis of organizational culture in construction. In this field, it is very important to mention Charles Handy (1979) and Fons Tropicenaars (1994). These authors differentiate organizational cultures focused on hierarchy from cultures based on egalitarianism. Authoritarian organizational cultures assume strict control of subordinate workers, who do not have autonomy. Subordinate should simply obey the orders from powerful people inside the company. In contrast, egalitarian organizational cultures allow autonomy and discretionary power of subordinate workers. In egalitarian cultures, communication goes in both directions – from top to bottom and from bottom to the top. It should be stressed that neither hierarchical nor egalitarian cultures are universally applicable. It would be not just illogical, but also inefficient to apply strict hierarchical culture in an academy of art. Similarly, no military in the world is based on egalitarian culture. Different occupations demand different cultures in general and different type of power structure, as an element of organizational culture (see Chatman and Jehn, 1994, and Deal and Kennedy, 1982).

So, is organizational culture in construction business closer to authoritarian or to egalitarian culture? Research conducted by Faculty of civil engineering, University of Zagreb, provides an unequivocal answer: organizational culture in construction is very similar to military, i.e. to authoritarian culture. Haladin (1993: 252) found that “on building sites we have frequently methods of control similar to those in military... Semi-military hierarchy and discipline is combined with patriarchal and informal elements of organization.” Study by Šandrak Nukić and Huemann (2016) confirmed this finding. According to the authors, construction companies in Croatia currently function with domination of the hierarchy type of organizational culture. Furthermore, the study identified the clan as the preferred culture type in Croatian construction companies. If we connect now research about the differences of national cultures with the research about organizational cultures in construction (focused on level of authoritarianism) we may hypothesize that those national cultures which accept high distance of power as normal, even desirable, can be abundant reservoir of working force in construction, especially reservoir of unskilled workers. Of course, additional empirical research should give proof for this theoretical assumption.

Some statistical data also support this assumption. For example, construction companies in the USA hire huge number of unskilled workers from Latin America. According to United States Department of Labor (2014)<sup>24</sup>, 27.3 percent of workers in construction were of Hispanic or Latino ethnicity although Hispanic and Latino workers constitute just 16.1 percent of working force in the USA. Of course, one of the reasons why so many workers in construction are from Latin America is also connected with their educational level. However, there is no doubt that organizational culture in construction matches national culture of these workers. Accordingly, construction workers from Latin America can accept organizational culture in construction companies more easily than other immigrants to the USA and more easily than American themselves, who do not accept power distance equally as Latin American workers (Hofstede’s index for the USA is 40 and for Mexico 81). Furthermore, very workers from Latin American countries perform well in authoritarian type of organizational culture. According to Janjićević (2013: 616), productivity of workers in Mexico is higher when leaders implement authoritarian style of leadership than when they implement democratic style of leadership. Accordingly, workers from Latin America do not have much problems with authoritarian style of leadership in construction business. Similarly, people from former Yugoslavia, who also accept power distance relatively easily (Hofstede’s index 76), have been readily accepted in Germany for work in construction. Dissolution of Yugoslavia showed differences between national cultures. However, these differences are not huge (Hofstede’s index for Croatia is 73, for Serbia 85 and for Slovenia is 71).<sup>25</sup> On the other hand, for people from countries with low level of power distance it is more difficult to accept strong discipline which prevail in construction.

By now, construction companies have been analyzed as unitary actors. However, organizational cultures of big companies have also subcultures. Therefore, it is important to compare organizational subculture of leadership of construction companies with organizational

<sup>24</sup> <https://www.bls.gov/opub/ted/2015/hispanics-and-latinos-in-industries-and-occupations.htm> (accessed 24 April 2019)

<sup>25</sup> In Janjićević (2013: 556, 569)



subculture of manual workers. This analysis is further complicated by the fact that modern construction companies work in a global environment. Accordingly, the next section analyzes the influence of globalization on organizational culture in construction business.

### **3. Organizational culture in construction: global trends**

The previous section showed that national cultures that are relatively authoritarian and collectivistic are similar to organizational culture in construction (if Haladin et al., 1989 and Šandrak Nukić and Huemman, 2016, empirical research is correct). Accordingly, for workers from these national cultures (especially unqualified ones) it is relatively easy to accept organizational culture of construction companies and, therefore, construction business relatively easily absorb immigrants from authoritarian national cultures. However, globalization has strong influence on organizational culture in construction as well as in other branches of economy. Today, we may find many companies in which people from France, Philippines, Germany and India work together in Argentina for a company that has the headquarter in the USA. So, what happens with organizational culture in general, and with organizational culture in construction, in particular, when people from different national cultures work together? If people from countries with authoritarian national culture work together with people from countries with democratic national cultures, which type of culture prevails? This is a general question, but it is even more important, for this article, to analyze which kind of organizational culture will prevail in construction companies with employees from very different national cultures? Situation with construction companies is even more complicated because managerial style originates mainly from countries with democratic cultures. However, authoritarian style (as it was elaborated above) prevails on construction site. This question is especially important today, because it is still disputable whether multiethnic structure of a company is an advantage or an obstacle for successful projects. According to Janićijević (2013: 543-4), when two colleagues from very diverse cultures, say Swedish and Japanese, need to collaborate on a joint project they can take advantage of the synergy of diversity and create something new and better. However, it is also possible to enter into conflict. Whether multiculturalism is a competitive advantage for the company, or the cause of poor performance depends on the way in which the company is managed.

So, how global companies should be managed if they have workers with different national backgrounds and, consequently, workers that are socialized in different national cultures? There are two competing theories that try to answer this question – the theory of convergence and the theory of divergence. According to the theory of convergence (for example, Guillen 2000, Ralston, et al., 1997), we may expect a universal organizational culture of global companies. According to this theory, only companies that accept the best managerial approach and the best organizational culture, in certain type of business, can survive on the global market. National cultures that differ from this imagined best model should adjust themselves to this universal model or face the risk of economic decline. Furthermore, modern managers are educated on similar textbooks (usually American ones), their training programs are similar and global companies expect from them to accept organizational culture based on Anglo-Saxon national culture. In addition, English language became *lingua franca* and spread of this language also promotes Anglo-Saxon national cultures and their organizational culture

(see Gupta and Wang, 2003). Janjićević (2013: 675) summarizes the essence of convergence theory: “globalization for supporters of convergence means the expansion and general acceptance of the cultural values of Western civilization, and especially of American national culture.” This means that by researching organizational culture of American companies we predict future of organizational culture of companies around the world.

Indeed, managers of global companies, no matter of their origin, have many similarities, which is mainly based on similarities of education.<sup>26</sup> In a way, they develop an organizational subculture which is similar in different parts of the globe. In this respect, they are like medical doctors, who apply similar procedures around the world and this similar approach shapes organizational culture of medical doctors, which become gradually a universal organizational culture in this profession. Consequently, managers in certain branches of economy will become more and more similar and their national culture will become less and less significant. In short, according to the theory of convergence, we may expect that global construction companies (to return to the main topic) will have, in the future, very similar organizational culture everywhere.

However, the theory of divergence (see Laurent, 1983 and Ralston’s et al., 1993 overview of this approach) claims that neither universal global culture nor universal organizational culture exist. Even universal Western organizational culture does not exist. American organizational culture, even in the same brunch of economy, differ from organizational culture in Germany, France and especially from organizational culture in Japan. All these organizational cultures are based on national cultures. Hence, organization culture will always be influenced by nationality of their managers and they will be different in different parts of the globe.

Nevertheless, we also have the third approach concerning the issue of global organizational culture – crossvergence theory (see, for example, Gupta and Wang, 2003 and Vertinsky, et al., 1990). This theory claims that organizational cultures will, in the long run, really converge. However, this convergence will not be just passive acceptance of American organizational culture but rather a mixture of different national organizational cultures.

So, which one of these theories is the most persuasive? It is difficult to answer on this question because all three theories have strong arguments in their favor. However, all three of them cannot be right because they oppose each other. Probably the closest answer to the question of validity of this theory is that global economic trends changed their persuasiveness. In 1945, approximately half of global GDP was produced in the USA (see Maddison 2018). Therefore, other western economies started to copy American organizational culture, which is in accordance with convergence theory. The same happened after 1990. The collapse of the Soviet bloc established the USA as only World’s superpower. Therefore, great majority of countries started to copy not just American economic model but also managerial style and organizational culture (Bogićević at al, 2012). Once again, convergence theory seemed right, this time not just in the West but also on global scale.

<sup>26</sup> (see Janjićević,, 2013, especially pages 675-6).

However, economic success of other countries, especially during the period from 1950-1990, was a strong argument in favor of theory of divergence. Success of Asian tigers and especially tremendous economic growth of Japan, during that period, showed that there is no universal organizational culture applicable to all countries. Japanese organizational culture, based on collectivism, differs significantly from American organizational culture based on individualism. Nonetheless, another country has challenged universality of American organizational culture even more – China. Tremendous economic growth of this country, during the last 40 years, is probably the strongest test to universality of American organizational model and American organizational culture. China's companies differ even more from American ones than Japanese companies because state-owned companies are still the backbone of China's economy (Qingqing, 2018). Dominance of Communist party in this companies, different property rights in China (this country does not have private property in Western sense of this word), different value system (based on a mixture of Confucianism, Marxism and liberalism) produced organizational culture which is different from one that dominate in the USA and in the European Union. It is important to note that, on the basis of this economic system, China become the leading economic power in the World in 2012 (based on purchase power parity).<sup>27</sup> All these arguments challenge the theory of convergence.

Yet, there is no doubt that modern information technology and advance in transportation enables contacts of different national and organizational cultures. As Janićijević (2013: 543) correctly pointed out, “in modern global companies it is not at all unusual that an engineer from India, along with colleagues from Britain, the Philippines and Egypt, works in the branch of that company in Brazil.” Furthermore, they learn from each other and this fact supports crossvergence theory. Inadequate organizational cultures will not be able to compete at the global market and, accordingly, global companies will introduce in their organizational culture's elements from other organizational cultures that are proven to be successful (for organizational learning see Lewin, 1951). Very China become so successful when it started to incorporate elements of Western organizational cultures. It is more difficult to incorporate China's organizational culture in the West (one of the obstacles is Western sense of superiority) but contacts between China's and Western companies will, for sure, enhance mutual learning. In short, crossvergence theory is, at present time, supported more by economic facts than two other competing theories.

An additional issue with theories mentioned above is that they try to identify general trends with organizational culture, which is, of course, very valuable task. However, not all branches of economy have same trends because type of activity influences organizational culture (Brown, 1995). To illustrate, production of armaments is always connected with certain level of secrecy. Although we have global market for weaponry, very production is under control of national governments. Accordingly, national culture has here much stronger influence than in branches of economy which are fully globalized, (see, for example, Soeters at al, 2006). Hence, convergence theory can be valid in one brunch of economy and divergence theory can be valid in another one.

<sup>27</sup> <https://www.cia.gov/library/publications/the-world-factbook/rankorder/2001rank.html#ch>, (accessed 29 May 2019)

Furthermore, in addition to general organizational culture of a company, huge companies may have different subcultures inside this general culture. For example, it is possible that top division of company follows trends identified by convergence theory, having at the same time unskilled workers who makes a mixed culture formed by workers from different national backgrounds, i.e. subculture formed in accordance with the crossvergence theory.

So, which trends we have in construction companies? Do they follow trends identified by convergence, divergence or crossvergence theory? The first thing that should be mentioned is that construction companies follow general trend of globalization. As a matter of fact, construction companies have long tradition of hiring foreign workers, especially unskilled foreign workers. In addition, capital infrastructural projects have involved construction companies from different nations. For example, Croatian construction companies worked, even during the period of socialism, in many foreign countries, especially in countries that belonged to Non-alignment movement (see, for example, Haladin et al, 1989, about involvement of Croatian construction companies in Algeria). Accordingly, organizational cultures of different construction companies, based on different national cultures and workers from different nations, have been interacting for decades. It is logical to expect that interaction of different organizational cultures have occurred during this process. Big construction companies even organize seminars for managers in order to teach them about different cultures of workers from different nations.<sup>28</sup> This process is in accordance with crossvergence theory.

However, trends identified by convergence theory also exist in construction companies. Dissolution of Soviet bloc produced spread of Western values (especially American ones), western business practices, managerial styles and organizational culture of western companies (see Bogićević at al, 2012). Additionally, new generations of engineers and managers are educated on textbooks written by western authors. International contacts between managers occurs in English language, which also brings Anglo-Saxon culture, including Anglo-Saxon organizational culture (see Gupta and Wang, 2003). Seminars and conferences (like this one in Zagreb) are based on patterns established in Western culture. Consciously or unconsciously, a universal type of organizational culture, which is predominantly American organizational culture, has been accepting, especially on behalf of top management of construction companies. In a word, it is possible to identify, in construction companies, trends explained by convergence theory. However, this is still assumption, based on convergence theory, which should be empirically tested in construction companies.

Still, it is also possible to identify, in construction companies, trends explained by divergence theory. Analysis in the previous section showed that attitude toward power distance is not the same in different national cultures. If we have top management educated in national settings that promotes egalitarianism and manual workers socialized in authoritarian cultures, divergence will occur not just between construction companies but also inside them. If it is true that managers accept American style of organizational culture, as claimed by convergence theory, than attitude toward power distance differ between managers (Hofstede's index for the

<sup>28</sup> One of the employees of Bechtel informed author of this article about this praxis.

USA is 40) and manual workers inside construction companies, who frequently come from national cultures with much higher power distance.

It was already mentioned that there are three main sources of organizational culture – national culture, type of economic activity and founder or dominant leader inside an organization. Previous section in this article showed that construction, as a type of economic activity, foster certain level of authoritarian organizational culture. Accordingly, national cultures that accept authoritarian model are better suited for providing working force for construction companies, especially for lower hierarchical level of these companies. Many leaders of construction companies are also from authoritarian cultures, especially those managers which were socialized and educated in countries where authoritarian culture dominate. However, globalization connects different national cultures. As a result, crossvergence (interaction) of these cultures occurs. However, top level management of construction companies are influenced by Anglo-Saxon model of organizational culture, which is in accordance with the theory of convergence. Accordingly, subculture of managers is different than subculture of manual workers. In other words, separation of organizational culture occurs inside construction companies (in subcultures) which is in accordance with the theory of divergence.

#### **4. Conclusion: national, global and organizational culture in construction**

This article applies theoretical analyzes of national and organizational cultures in the age of globalization on analysis of organizational culture in construction. Empirical data that support this analysis are mainly Hofstede's (2001) analysis of national cultures, Haladin's at al. (1989) analysis of organizational culture in construction and data provided by authors that support theories of convergence, divergence and crossvergence of national cultures in global environment. The main findings of this article are that organizational culture in construction matches authoritarian national cultures. Moreover, inside organizational cultures in construction it is possible to find different subcultures. Top level management is mainly influenced by Anglo-Saxon managerial style and organizational culture and on this level convergence of national and organizational cultures prevails. It can be predicted that on this level we will have very similar organizational subculture in the future. In contrast, lower levels of subculture of construction companies is still characterized by multiculturalism. One of the reasons for this is language barriers on the lower levels of construction companies (construction companies traditionally employs foreign workers). Hence, divergence will prevail on this level for much longer period.

The main weakness of this article is that theory is supported by limited empirical data and data that are used are from secondary sources. Therefore, theoretical models here should be enhanced, in the future, by the following empirical research. First, it should be checked whether value system of management is different from value system of subordinate workers. It is especially important to compare attitude toward authoritarianism on different levels of construction companies. The best method for making such analysis is survey. Second, it should be checked whether construction workers with different national backgrounds really differ in their acceptance of organizational culture of construction companies. There have been some

studies on that topic during last few years. Theoretically, as this article explained above, manual workers from authoritarian national cultures have less problems in accepting organizational culture of construction companies. Study by Šandrak Nukić and Huemman (2016) about organizational culture of the Croatian construction industry confirms this hypothesis. However, this hypothesis should be further tested by other surveys and interviews. Finally, we need more empirical analysis about similarities and differences between managers of construction companies. These empirical analyses should check whether their organizational subculture really become more and more similar, as this article suggest. In short, this article provides a theoretical framework for further empirical analyses about the influence of national culture on organizational culture in construction in the age of globalization.

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# Barriers to Implementing Quality Management System in the Industry 4.0 Era

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## Abstract:

Industry 4.0 is currently a subject of much discussion in the academic and industries. It promises numerous gains for its successful applications in all domain. Based on this, the construction sector aims at improving quality management. However, there have been challenges to the implementation of the quality management system in the industry 4.0 era for construction activities. The study conducted a narrative literature review to address the barriers to implementing quality management systems for construction 4.0 as an implication for South African construction industry. The outlined challenges drawn from relevant literature are further categorized into the three key concepts of Industry 4.0. It addressed the challenges in terms of a factory, people, and product, where the baseline is the ISO 9001 system to quality management. The study finds out that the barriers to implementing a quality management system in the industry 4.0 era can be grouped under a vertical category, horizontal category, and end-to-end integration category. The study offers suggestions to the outlined problem as well.

*Keywords: Industry 4.0; Quality Management Systems; ISO 9001; construction*

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## 1. Introduction

Industry 4.0 is a new paradigm shift in academia and the industry. It promises numerous gains for its successful applications in all domains (Zhong *et al.*, 2017) when applied. Industry 4.0 has been described to have three key aspects. They are vertical integration, Horizontal integration, and end-to-end integration (Demartini and Tonelli, 2018). In this era of the fourth industrialization, enterprises seek to retain competitiveness while achieving high customer and product satisfaction (Zaidin *et al.*, 2018). Quality management is, therefore, germane to the success of a business enterprise. This makes it imperative to continually seek processes to improve customer satisfaction. Recently, modern manufacturing (or construction) seeks to absorb industry 4.0 to improve its innovation process.

Globally, industries are absorbing the industry 4.0 paradigm, although at different paces. Yet, there are challenges to the implementation of a quality management system (for example, the ISO 9001 procedure) in the industry 4.0 era for construction activities. The aim of industry 4.0 is to solve problems arising from process, technology, and people which affects quality management (Demartini and Tonelli, 2018). This implies that enterprises must keep up with the pace of the industrial revolution. In the context of this study, the terms fourth industrial revolution, 4IR, and 4th industrial revolution are used interchangeably because they equally described the same concept. This study seeks to address quality management from the industry 4.0 perspective, particularly, to discuss the possible challenges posed to it while transitioning from the traditional mode of construction to that of industry 4.0. After the background study,



brief literature on the topic is discussed. Thereafter, the methodology applied, and the result of the study are discussed. The preceding section discussed the findings. Lastly, the study draws out conclusions which justified the purpose of the study.

## 2. Literature Review

Quality Management System (QMS) is synonymously discussed alongside other business improvement tools like ISO 9001, Lean manufacturing and Six Sigma (Kikuchi and Suzuki, 2018). QMS is a set of procedure, policies and processes aimed at achieving higher customer satisfaction through competitiveness by structured documented information. As such, it is a subject commonly addressed in academia and the industry (Lahidji and Tucker, 2016; Ondra, Tuček and Rajnoha, 2018). The attributes of quality management are goals, rules, feedback and participation (Beard-Gunter, Ellis and Found, 2019) customer satisfaction, continual efficiency for waste reduction, top managerial competencies and improvement documentation like the ISO 9001 system. Therefore, enterprises seek to focus on quality management (Foidl and Felderer, 2016). The construction industry is an example of a competitive enterprise which seeks to remain competitive by improving business process.

The construction industry plays key roles in the growth of both developing and developed economies. It contributes to the Gross Domestic Product (GDP) of such economies (Oesterreich and Teuteberg, 2016). This it achieves by continually seeking to improve the competitive edge for the business process (Renukappa *et al.*, 2016). In the current era of industry 4.0, construction industry like other sectors seeks to incorporate automation to improve its business process. As such, Construction 4.0 as a term is used to describe construction in the industry 4.0 era is aimed at automation and digitalization of construction activities (García de Soto *et al.*, 2019). The core of industry 4.0 paradigm is to improve product quality and productivity. Yet, construction faces more challenges to productivity compared to the manufacturing sector (Dallasega, Rauch and Linder, 2018). This is because industry 4.0 is not well rooted yet in the construction industry (Oesterreich and Teuteberg, 2016), particularly in the developing economies.

Globally, the traditional method of construction work has reached its limits. Developed countries like the USA (Bogue, 2013), Netherlands (Bos *et al.*, 2016), Italy (Hasan, Al-Hussein and Gillis, 2015), China, the UK (Niu *et al.*, 2016) among others have embraced automation in construction industry like 3D printing, Robotics, Smart Helmet, Virtual Reality and the likes. On the contrary, developing countries have not reached the implementation level of automation in construction. For example, South Africa as a developing country is slowly absorbing the industry 4.0 concept compared to other developed nations (Pillay, Ori and Merkofer, 2016). South Africa seeks to improve its construction activities by gradually embracing digital transformation (Oke, Aigbavboa and Mabena, 2017). The aim of industry 4.0 is to improve the production process. Jong, Sim and Lew (2019) described that QMS like ISO 9001 use has a significant effect on construction project performance in Malaysia. However, there is a challenge is on how to use extensive information for quality management, of which industry 4.0 proposes a solution (Cattaneo *et al.*, 2017).

Based on ISO, quality management systems include quality planning, control, assurance and quality improvement. Although QMS is a common paradigm addressed in academics and the industry, most enterprises are struggling to accept incorporating it in the industry 4.0 era (Gunasekaran, Subramanian and Ngai, 2019). The traditional organizational culture to quality management must be addressed in line with the current industry era (Durana *et al.*, 2019). Various studies have outlined other barriers to a quality management system in the industry 4.0 era. Beard-Gunter, Ellis and Found (2019) described that although the core of QMS system like ISO 9001 is data management, it is a paradox that enterprises are struggling with the complexity of data for industry 4.0 in the construction industry. Similarly, a barrier to implementing QMS in the 4IR era for construction work is because the industry at its present state still relies more on conventional QMS procedures (Bihi, Luwes and Kusakana, 2018). Other studies have attributes problems arising from cost, time and quality, specification for construction projects, and complexity of construction processes as barriers to implementing QMS for industry 4.0 (Buckhorst and Schmitt, 2017; Akhund, Khahro and Siddiqui, 2018; Demartini and Tonelli, 2018), in the construction industry.

### **3. Methodology**

The literature review aimed at identifying current and relevant studies on industry 4.0, quality management, and how both can be incorporated to improve the manufacturing workspace. This narrative review is based database search from “Web of Science (WoS)” database and “Elsevier’s Scopus (ES)” collection. The study of Harzing and Alakangas (2016) opined that these databases provide adequate stability of coverage for scholarly publications. Previous studies have combined different databases for studies. For example, Ilangakoon, Weerabahu and Wickramarachchi (2019) study explored industry 4.0 and lean health using different databases. Also, Mongeon and Paul-Hus (2016) conducted a comparative analysis of WoS and ES collections.

This evidences showed that these databases are a sufficient source of data collection. The search applied adequate keywords such as “Industry 4.0”, “Quality Management”, and “Manufacturing”, “construction”, for this study. A total of 70 relevant articles from 2016-2019 were selected within this broad domain. Afterwards, screening was done on these articles by removing articles like “Book”, “book chapter”, “reports”, repeated articles were also removed. This resulted in the final use of 11 articles which were considered to be relevant and has high contributions. Therefore, the first step for the review is “Keyword search”, followed by “Article Selection”, “Article Screening”, “Review of relevant article”, and the last step is “documentation of review”.

### **4. Results**

The result of the selected article is presented in table 1 below. It showed the theme of the study and the research methodology applied for the study. There are eleven selected articles for the study. They employed both quantitative and qualitative research methodologies in the studies (see table 2). The distribution of such research approaches increased the validity of the research selected. Key themes (barriers) which are relevant to the aim of this study were also retrieved from the selected study. Subsequently, in table 3, the key barriers were grouped under

the three core aspects of industry 4.0 factory/process (vertical), people (horizontal), and product (end-to-end integration).

Table 1. Summary of Study reviewed

Authors	Theme (s) derived	Methodology
Beard-Gunter, Ellis & Found (2019)	Complex data	Systematic Literature Review
Bihi, Luwes, Kusakana (2018)	Traditional QMS	Literature Review
Durana et al (2019)	Quality Culture	Questionnaire Survey
Zaidin, et al (2018)	Complex data, huge investments; complex production	Literature Review
Demartini and Tonelli (2018)	An increasing level of variability	Systematic Literature Review
Buckhorst and Schmitt (2017)	The problem of Time, cost and Quality	Interview
Oesterreich and Teuteberg (2016)	Slow adoption of industry 4.0	Mixed Methodology
García de Soto et al., (2019)	Possibility of role change	Literature Review
Nowotarski, Paślawski & Kadler (2018)	Inadequate application of quality management systems	Case Study
Akhund, Khahro & Siddiqu (2018)	Unclear construction specifications	Questionnaire Survey
Stransky and Matejka (2019)	Manual QMS; Non-compliance with QMS procedures	Questionnaire Survey

Table 2. Distribution of Methodology in the selected study

The Methodology used	Percentage of occurrence
Literature Review	45.0%
Questionnaire Survey	27.0%
Mixed methodology	9.1%
Interview	9.1%
Case Study	9.1%

Table 3. The grouping of the barriers into Factory, People and Product

Factory / Vertical category	Horizontal / People category	Product /end-end category
complex data	Traditional/ manual method of QMS	problem of time, cost and Quality
Complex production	Quality culture	Inadequate application of QMS
An increasing level of variability	Problem of time, cost and Quality	Unclear construction specifications
Problem of time, cost and Quality	Slow adoption of industry 4.0	huge investments problems
	Possibility of role change	
	Unclear construction specifications	
	Non-compliance with QMS procedures	

## 5. Discussion of Findings

Three key aspects of Industry 4.0 are vertical, horizontal and end-to-end engineering integration. They refer to the factory for production, the team involved in the production and the value chain for product respectively (Wu, Wang and Wang, 2016). The group in table 2 above follows these aspects of industry 4.0 and are also based on the ISO 9001 quality management systems. Previous studies have of Foidl and Felderer (2016) and (Sony, 2018) also described the three aspects of applied industry 4.0.

According to table 3, the Barriers to QMS for 4IR in the Factor or vertical categories are complex data, complex production, increasing level of variability, and the problem of time, cost and quality. Beard-Gunter, Ellis and Found (2019) described that the complexity of data is a barrier to implementing a quality management system for industry 4.0. The study of Zaidin *et al.*, (2018) supported that industry 4.0 itself is categorized by a large volume of generated data. The failure to apply automation to validate customer satisfaction may arise from the complexity of the data involved. Another vertical barrier is the complexity of production. Zin, Nang and Kham (2018) described that the complexity of production is a challenge that can be managed with appropriate measures. The study of Zaidin *et al.*, (2018) also agreed that the complexity of production arises since industry 4.0 is challenged by repetitive complex work, which is the characteristics of the construction industry. This means the current technology has not been able to override complex production in construction.

An increasing level of variability refers to problems arising from dimensional changes related to people, process, and technology for the technical business process. Demartini and Tonelli (2018) opined that in the present industry and competitive era, it is difficult to achieve customer satisfaction which is one of the aims of QMS. This agrees with the findings of Schlüter and Sommerhoff (2017) that modern quality management measures are necessary for digital transformation. Lastly, under the category of horizontal barriers to QMS for industry 4.0, Buckhorst and Schmitt (2017) described that problems related to time, cost and quality affect QMS. Enterprise struggle to retain a competitive edge due to the problems arises from cost, time and quality. This also agrees with the problem of high investment in industry 4.0 for construction work (Zaidin *et al.*, 2018).

Horizontal or people category problem describes the traditional/ manual method of QMS, Quality culture, Problem of time, cost and Quality, Slow adoption of industry 4.0, Possibility of role change, Unclear construction specifications, and Non-compliance with QMS procedures as some barriers to QMS implementation for construction activities in the fourth industrial revolution. The problem of time, cost and quality appear as a similar barrier on the vertical level. It implies it is a problem which affects QMS on the factory and people level, for example, return on investment of getting an operational QSM certificate not being considered (Bacoup *et al.*, 2017), is a problem arising from the users of such procedure. Another problem is the culture of quality obtained in an enterprise. The traditional organizational culture to quality management must be addressed in line with the current industry era (Durana *et al.*, 2019). Also, the construction industry is slow to innovate in the current industrial era (Oesterreich and Teuteberg, 2016), because lots of enterprises especially those of the developing construction economies, still use the traditional method for quality management

(Bihi, Luwes and Kusakana, 2018). In another perspective, construction stakeholder feels threatened about job loss since machines are taking over the workplace (Zaidin *et al.*, 2018; García de Soto *et al.*, 2019). All these barriers sum up to influence QMS for construction 4.0.

Problems of time, cost and Quality, Inadequate application of QMS, Unclear construction specification, and huge investments problems are also described as barriers to QMS application for construction 4.0 in the end-to-end integration aspect of industry 4.0. Problems of time, cost and quality are prevalent across the three levels of vertical, horizontal and end-to-end. Inadequate application of quality management systems is a barrier posited by Nowotarski, Paślowski and Kadler (2018). It aligns with previous similar studies of (Oesterreich and Teuteberg, 2016; Bihi, Luwes and Kusakana, 2018). The unclear specification makes the construction process difficult and tedious (Akhund, Khahro and Siddiqui, 2018), especially when the ISO 9001 standard are not followed adequately (Stransky and Matejka, 2019). These barriers relate to implementing QMS for construction activities on end-to-end integration category of industry 4.0.

## 6. Conclusion

This study aimed at addressing the barriers to implementing a quality management system for construction activities in the industry 4.0 era. It conducted a narrative review of relevant selected literature on the topic. The findings from the study revealed that the barriers to QMS for construction 4.0 can be grouped under process, people, and technology. Therefore, the barriers are categorised under the vertical category (factory for production), the horizontal category which involves the users carrying out the production, and the production process itself, which is the end-to-end integration process. A prevalent problem in these three categories are the problems related to process, people and technology.

As an implication, it is suggested that a platform like virtual quality management system should be introduced to enhance QMS for construction 4.0. Virtual quality management (VQM) system makes it possible to create a similar simulation interface for the proposed activity even before it started. This is done by having a knowledge of product quality, environmental factors influencing construction, and process knowledge. This will enhance virtual quality management to overcome the challenges to implementing a quality management system for construction 4.0 during the planning phase, by avoiding problems like delay (in time), reduced production quality, and cost overrun can be avoided when actual construction starts

In addition, industry 4.0 must provide tools and platforms to improve high-quality construction products which increase competitive edge and achieves customer satisfaction, a goal of QMS like ISO 9001 since it will be vital for economic, human and technical decisions. All these can be achieved through improved management and optimization processes. It is also proposed that maximizing quality and cost within a stipulated time frame will enhance enterprise sustainable productivity. This study has been able to contribute to the body of knowledge by identifying the barriers to quality management for construction work in the context of industry 4.0. Hence, the study is applicable to the construction industry both in developed and developing countries like South Africa especially since a common problem of

time, cost and quality identified in the study is prevalent in both economies. This research is however limited by study methodology applied. It also limited by the number of selected studies reviewed. As such it is open to further discussion. It is suggested that future quantitative approach should be used to study and proffer solution to the problems affecting the quality management system in the industry 4.0 era.

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# Perception of the Concept of Goodwill in Construction Industry: Case Study of Czech Companies

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## Abstract:

Goodwill represents an integral part of the value of a construction company. In the Czech Republic, the concept of goodwill appeared in accounting in 2003, while the method of determining its value or depreciation differs from foreign IFRS or US GAAP standards. With respect to the specificity of the goodwill concept in the Czech Republic, this article focuses on the perception of goodwill in the construction industry environment. Quantitative data has been collected in the form of an online questionnaire survey and then supplemented by qualitative data obtained through structured interviews to reach the research objective. Data has been evaluated using table and graphical depiction and relative importance index. It has been found out that a large proportion of informants has no clear idea of what the goodwill concept means, however, generally they perceive the importance of goodwill for their companies. The results of this study represent a preliminary analytical insight into the issue being studied, which forms part of a broader research task that should lead to creation of a methodology for the objective determination of the construction company goodwill value in the long-term horizon.

*Keywords: Goodwill; construction company; intangible assets; accounting standards, survey*

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## 1. Introduction

Goodwill, which represents the core topic of this article, is not clearly defined. However, it is a concept that has been relatively widespread and discussed worldwide since the 16<sup>th</sup> century. Over time there were also a lot of different views and definitions of goodwill that even deepened in the 20<sup>th</sup> and 21<sup>st</sup> centuries, however still have not been unified. The same applies to the calculation, reporting and accounting of goodwill. In the Czech accounting, this term appeared as late as in 2003, which is quite recently compared to other countries where it has been operating for much longer time.

Even though the concept of goodwill is not precisely defined, it can be said that it is essential for companies and forms an integral part of their value. It is particularly important in the construction companies, as construction industry is a field where there is a lot of competition and without good name, high quality work, good relationships with business partners, employees and customers, companies could disappear. It is therefore essential that companies were constantly working on increasing their value and quality of their work due to the high competition on the current construction market.

The aim of this article is to find out how the concept of goodwill is perceived and understood in the environment of Czech construction companies. The article is structured as follows: firstly, the concept of goodwill in relation to accounting is presented and the

international, American and Czech national accounting standards are compared; secondly, the findings resulting from the questionnaire survey and controlled interviews are presented and discussed.

This article was developed as a part of a broader research activity focusing on the valuation of goodwill in construction companies. Partial findings concerning the perception of the concept of goodwill in the chosen study area, which is the Czech Republic, are presented in this paper as part of the initial partial ongoing research phase.

## **2. Understanding of goodwill in the light of accounting**

### *2.1 Goodwill as a concept*

Originally, the concept of goodwill was defined as "good will" in the 16<sup>th</sup> century, which means well in the future (Kulil, 2014). Goodwill can be regarded as a legal, economic, and also an accounting concept, which raised many questions among the professional public in the 19<sup>th</sup> century. The first reference to the goodwill concept arose from legal disputes, and subsequently it used to be understood more in the economic sense, which later turned into an economic-accounting connotation (Zelenka, 2006).

The diversity of approaches has deepened further in the 20<sup>th</sup> and 21<sup>st</sup> centuries, as evidenced by a number of definitions that focus mainly on the economic approach to this concept. For example, Kulil (2014) states that, according to established international practice, goodwill means a good name of the company which delivers improved economic results, based on appropriate business policy, resulting from the relationships with the customers, promotion and advertising. Hughes characterized goodwill in the historical accounting encyclopaedia as a difference in the ability of one company to generate profit compared to another or average company. He also stated that this concept was originally derived from the good feeling or good will of the entrepreneur to the customer (Zelenka, 2006). According to Yang, who defined goodwill in his book *Goodwill and Other Intangibles* in 1927, this concept represents current or capitalized value of the estimated future profit of the established company above the normal results that could reasonably be expected to be realized by a similar or newly established company (Zelenka, 2006).

In the Czech accounting area, the concept of goodwill appeared as late as in 2003. Until then, it was only used as the provision for acquired assets. In that year, however, an amendment to accounting regulations came in force and the concept started to be divided into two parts (Mařík, 2018), namely:

- Goodwill, which forms part of intangible fixed assets,
- Valuation of the difference to acquired assets which forms a part of tangible fixed assets.

From an accounting point of view, goodwill is a positive or negative difference between the total value, that is, the purchase price of the company, and the sum of the prices of individual assets and liabilities, which means the company net assets. Depreciation is amortized on a straight-line basis over a period of 5 years from the acquisition of the company or from

the decisive date of its conversion to expenses, respectively, revenues in the case of negative goodwill. If the purchase price of the company changes, the value of goodwill or negative goodwill is adapted, without changing the depreciation period (Vomáčková, 2005).

The fact that someone buys at a lower or higher selling price than the book value of the asset after deducting liabilities has two rational reasons (Ryneš, 2013):

- The book value of acquired individual assets does not reflect the market value of that asset,
- Assets as a whole have a greater or lower value for the buyer (company) into which it is put, than is the asset book value after any revaluation of individual assets by virtue of acquiring a business network and clientele, goodwill or liquidation of the company.

It is important to consider goodwill as a complex issue. The literature distinguishes between two segments of goodwill, which are personal and enterprise goodwill (Fargher, 2018). According to Fargher, personal goodwill exists when personal reputation, expertise or contacts give the company its intrinsic value while stronger enterprise goodwill is found in companies with proven and documented operating systems, reliable suppliers, larger and diverse management roles, replaceable individuals, prime locations or independent traffic flow. It has also been reported, that the higher the marketing concentration, the more the goodwill affects the long-term financial performance of the company (Li and Sun, 2016). A study by Devalle and Rizzato showed that 94% of companies have goodwill in their financial statement.

## *2.2 Intangible assets*

In the Czech Republic, intangible assets are primarily concentrated on assets that can be viewed from both tax and accounting point of view. It is accounted for as intangible fixed assets and includes formation expenses, research and development intangible assets, software, valuable rights, goodwill, emission allowances and preferential limits. It is created as the difference between the valuation of the company and components of the property, which are reduced by liabilities (Svačina, 2010; Mařík, 2003).

Intangible assets transactions have direct impact on the accounting and tax picture of the company in the Czech Republic and may thus affect the choice of using which method intangible assets will be valued by (Uminská, 2013).

Intangible assets are governed by basic and tax regulations for entrepreneurs in the Czech Republic, namely:

- Act No. 563/1991 Coll., On Accounting, as amended,
- Decree No. 500/2002 Coll., Implementing certain provisions of the Accounting Act (formerly double-entry bookkeeping),
- Czech Accounting Standards for Entrepreneurs No. 013 – Fixed Tangible and Intangible assets,
- Act No. 586/1992 Coll., On Income Taxes (Svačina, 2010).

Internationally, intangible assets are generally recognized assets for any asset, including property. International Accounting Standards IFRS 3, in the Intangible Assets section of IAS 38, aims at describing approaches to accounting of the above-mentioned intangible assets. Standards require from the accounting entities to recognize intangible assets only if the criteria are met and they further specify the calculation of the book value of intangible assets in case of intangible fixed assets (Kulil, 2014).

### *2.3 Accounting Standards*

This part of the article focuses on the introduction and comparison of selected standards, namely international, American and Czech national valuation standards. Internal accounting does not fully address these standards, as such accounting is not governed by laws and regulations.

### *2.4 IFRS*

IFRS stands for International Financial Reporting Standards. They are used in more countries of the world, including Europe. This accounting system is based on principles that are not generally applicable rule of law and have about 1,400 pages. It is therefore up to each accounting entity how they compile their chart of accounts and produce their statements, which, however, must provide a true, complete and faithful image of the company about its actual financial condition and business results. Goodwill is understood as the difference between the price paid for a business unit and the real value of the net asset (Jílek, 2018).

IFRS was created in 2001 and replaced IAS, which were international accounting standards that originated from 1973 to 2000 period. The IAS usually only adopted some parts of the US GAAP and thus represented their abbreviated form. By 2005, about 300 companies had used this accounting system, however, since then, the number has risen to 7,000 companies. Today, the system is used by more than 80 countries worldwide (Jílek, 2018).

### *2.5 US GAAP*

US GAAP stands for US Generally Accepted Accounting Principles which are generally accepted accounting principles in the USA. This accounting system is based on very detailed rules. These are described on approximately 17,000 pages, which is a high number compared to IFRS. Goodwill is recorded in them as the excess of cost of acquisition price over the real value of acquired net assets if the book amount of goodwill exceeds the initial real value (Jílek, 2018).

The American accounting system has been developing since the late 1920s as a response to the global economic crisis and has been in use for over 80 years. It is used only in the USA, where there are now more than 10,000 companies (Jílek, 2018).

### *2.6 Czech Accounting Standards*

CAS is an abbreviation for Czech Accounting Standards issued by the Ministry of Finance of the Czech Republic. Goodwill is considered by them as intangible fixed assets irrespective of their valuation (Lukášová, 2012).

Czech accounting is currently in conflict with IFRS and US GAAP, because it is possible to account the same facts differently, which is not possible according to the international and American standards. They apply to all accounting entities, regardless of size, that a particular transaction will have the same economic benefits and risks for each entity. Accounting must be, according to both IFRS and US GAAP understandable and the same for all entities, well-arranged, sufficiently detailed and above all low-cost and with clear rules (Jílek, 2018).

Czech standards are thus not unified with IFRS and US GAAP, but they are being worked on, especially for higher clarity and simplification. Since May 1<sup>st</sup>, 2004, all companies that prepare their consolidated and separate financial statements must comply with IFRS. In addition, almost all banks and some financial institutions have already been using IFRS primarily for the purpose of accounting for financial instruments or valuations since January 1<sup>st</sup>, 2018. While not as detailed as US GAAP, IFRS are still more detailed than the Czech Accounting Standards, therefore most of the entities try to follow these standards in the Czech Republic (Jílek, 2018).

Regarding to the development of goodwill reporting according to CAS, various options for the emergence of goodwill resulting from the occurrence of a business combination that is subject to the recognition and accounting procedures are referred to (Zelenka, 2006). They are:

- Purchase of a significant share of the former company,
- Purchase of net assets of the company
- Mergers.

## 2.7 Comparison of IFRS, US GAAP and CAS

Table 1. Comparison of Accounting Standards

	IFRS	US GAAP	CAS
Year of the standard origin	2001 (replaced IAS that were created in 1973-2000)	1934	1990
Goodwill depreciation	Not applicable Goodwill is not depreciated but is reviewed annually for value reduction. The test is performed at the level of the cash-generating unit or the group of cash-generating units.	Not applicable Goodwill is not depreciated but is reviewed annually for value reduction. The test is performed at the level of the cash-generating unit or the group of cash-generating units.	Required Depreciation is amortized on a straight-line basis over a period of 5 years from the acquisition of the company or from the decisive date of conversion to costs, respectively revenues in the case of negative goodwill. If the purchase price of the company changes, the value of goodwill or negative goodwill is adapted, without changing the depreciation period.
Method of determining impairment (long-lived assets)	Required One-step approach requires the impairment calculation to be performed if impairment	Required Two-step approach requires the recoverability test to be performed first. If it is determined that the asset is not	Not Required There is no specific regulation or interpretation that would regulate the requirements and ways in which they could be used.

indicators exist. recoverable, an impairment loss calculation is required.

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The fundamental difference between these standards is that although the law may require the use of CAS, US GAAP and IFRS do not. The law is applied formally and procedurally, while US GAAP and IFRS are applied on a judgmental basis. Unlike the national regulations of the Czech or Slovak Republics, US GAAP and IFRS do not require any chart of accounts or property groups, no procedures or no statements. They only tell the accounting entities what and to what detail they should do in the reports. The decisive factor is the true representation of economic reality (Mládek, 2008).

D’Arcy and Tarca (2018) draw attention to the national differences regarding goodwill accounting and recommend that, when carrying out cross-country studies, to first understand the differences in institutional settings among the countries. For goodwill impairment, Seetharaman et al. (2005) provided list of external and internal indicators that play a significant role in impairment test, such as significant change in business climate, unanticipated competition, loss of key personnel or change in the name of the company.

### 3. Materials and methods

The analysis of the current situation shows that the concept of goodwill appears in the Czech Republic environment later than, for example, IFRS or US GAAP, so it is clear in the context of different accounting standards that the perception of this concept is specific. As the topic of this article is the issue of goodwill in the construction industry, the Czech construction sector was chosen as the study area.

Data collection took place both at quantitative and qualitative level. First, a questionnaire survey was conducted, in which 50 entities were asked to participate activity. Invitations containing a questionnaire link were sent by email to specific addresses during March and April 2019. In total, 21 valid anonymous responses were obtained, representing a 42% response rate. The questionnaire contained a total of 12 questions, first two of which surveyed the basic data on informants (the size of the company measured by the number of employees and the length of its existence on the market). Other questions were related to the concept of goodwill and related aspects. The questionnaire used closed and semi-closed questions which, in addition to the predefined answers, allowed to give informants’ own answers. The items aimed at determining the significance of selected facts which were evaluated using the 5-point Likert scale of assessment, using the Relative Importance Index (RII) according to the following equation:

$$RII = \Sigma w / (A \times N) \quad (1)$$

where:

$\Sigma w$  – sum of grades given to each factor,

A – max. assessment grade for each factor,

N – total number of informants.

The higher the RII value, the more important the factor being examined becomes, and vice versa. The RII value ranges from 0 ÷ 1.

Subsequent qualitative research consisted of three structured interviews with representatives of a selected Czech construction company. This approach has been deliberately chosen to determine whether the perception of goodwill concept is different even within the same company. The content of the interviews was thematically identical to the content of the questionnaire survey.

## 4. Results and discussion

### 4.1 Questionnaire survey

First two questions concentrated on the general information on informants, namely the size of the company measured by the number of employees (Q1) and the length the construction company existence on the market (Q2). As regards to Q1, companies were classified as micro, small, medium and large according to the Commission Recommendation of 6<sup>th</sup> May 2003 concerning the definition of micro, small and medium-sized enterprises. The micro category included 5 companies, 10 companies belonged among small enterprises, 1 to medium enterprise group and 5 to large enterprise group. Unfortunately, the low number of informants and their uneven distribution into size categories did not allow for more detailed analyses in relation to this categorical variable. As far as Q2 is concerned, the length of existence on the market is presented in Table 2. It is clear from Table 2 that both the companies operating for relatively short time (for less than 5 years) and the companies operating on the market for a long time (for more than 10 years), participated in the survey.

Table 2. Information on informants – length of the existence on the market

Length of the existence on the market (years)	Number of informants
< 6	8
6 - 10	7
11 – 20	3
> 20	3

The second part of the questionnaire was focused on the issue of goodwill concept itself. Question Q3 investigated whether the construction companies under research had ever encountered this concept, with 18 informants answering yes and only 3 informants responding not (small and micro companies). It can therefore be assumed that most informants have an idea of what this concept means and how their company works with it.

Question Q4 focused on the specific meaning of the goodwill concept when informants answered which notions are related to the meaning of the goodwill concept. It was a semi-closed question where informants could choose from predefined answers, but also add their own answers. Table 3 shows that 74% of informants believe that the concept of goodwill primarily represents a good name of a company. Frequent answers also included good relations

and contacts with suppliers and clients (38%), company image (38%), market position of the company (29%) and customer perception of the company (24%). Only one informant used the possibility of his / her own answer (good and quality work), however this answer can be assigned to the predefined category of the quality of the performed work.

Table 3. Meaning of the goodwill concept

Notion related to Goodwill	Absolute (Relative) frequency
Good company name	15 (74.1%)
Company image	8 (38.1%)
Good relationships/contacts with suppliers, customers, investors	8 (38.1%)
Market position of the company	6 (28.6%)
Perception of the company by customers	5 (23.8%)
Quality of work performed	3 (14.3%)
Experienced professionals in the field	2 (9.5%)
Good and quality work	1 (4.8%)

As the informants had the opportunity to give multiple responses, Q4 question was also analysed from this point of view (see Figure 1). The graph shows that informants most often associated the concept of goodwill with only one specific term (61.9%), however, there were also informants who listed 5 or 7 items (9.5% and 4.8% respectively). In the context of these results, it is clear that an absolute majority of informants perceive the concept of goodwill from a very narrow perspective, although the concept of goodwill is a much more complex issue which represents the good name of the company, how the company can develop its relations with suppliers, customers, investors and employees, what is the customers' perception of the company, how well they perform their work and what employees the company chooses for its activities. It is clear, therefore, that companies do not have the information about this issue so that they can effectively improve their goodwill value or use it to their advantage.

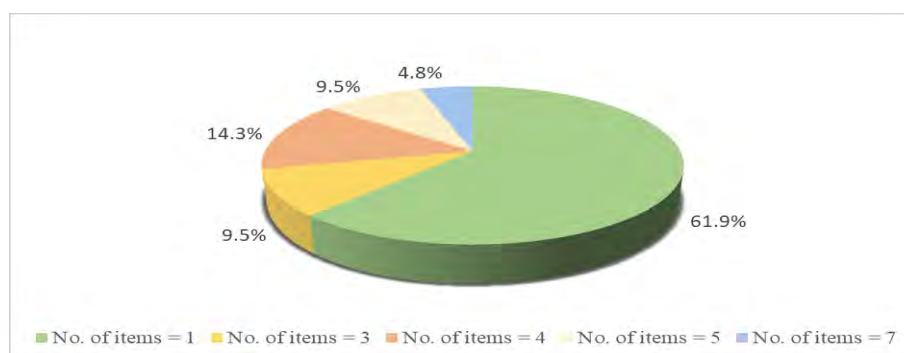


Figure 1. Evaluating the complexity of the perception of the goodwill concept (showing the relative frequencies of notions related to the goodwill concept)

Question Q5 focused on assessing the significance of goodwill for a construction company. The evaluation was done on a 5-point Likert scale, where ranking 5 was the most significant and ranking 1 was the least significant. 9 informants rated this question at grade 5, 7 at grade 4 and 5 by grade 3, indicating that companies predominantly consider goodwill important or even the most important for their company. This corresponds to the value of  $RII = 0.838$ .



Other questions were about branding to see if companies can distinguish between the concept of goodwill and concept of brand. In fact, these terms work together and without a brand, the value of goodwill will never be as high as a good brand. However, the concepts are different and therefore it is desirable to find out what is the awareness of the informants about the brand and whether they are able to distinguish these two concepts.

All 21 informants have met the concept of brand name (Q6). What is their idea about the concept of brand was investigated by Q7 which was constructed in the same way as Q4 (i.e. semi-closed with the possibility of multiple choice). The results are shown in Table 4 from which it is clear that the majority of informants chose as a clarification of the brand name, the name of the company, distinguishing the company from the competitors, company image or customers' perception of the company. However, it can be observed that only 4 informants marked all options and the remaining 17 chose only some of the possible answers (see Figure 2). Similarly to the goodwill concept mentioned above, the concept of brand is a more complex issue and involves more possible answers than merely the company name, differentiating a company from competitors, customers' perception of the company or a quality guarantee.

Table 4. Meaning of the brand concept

Notion related to brand	Absolute (Relative) frequency
Company name	12 (57.1%)
Differentiation of the company from the competitors	10 (47.6%)
Company image	9 (42.9%)
Customers' perception of the company	7 (33.3%)
Guarantee of quality	6 (28.6%)
Better market orientation	4 (19.0%)

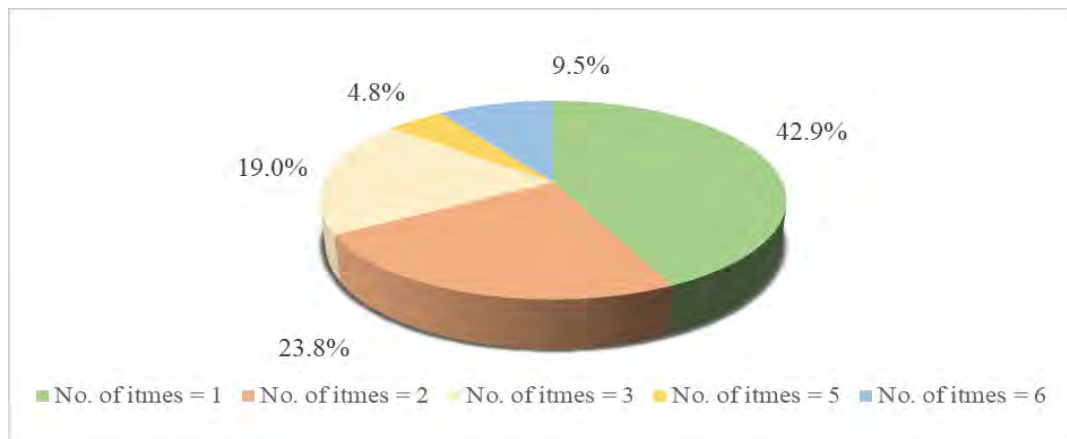


Figure 2. Evaluation of the complexity of the concept of brand perception (showing relative frequencies of the number of notions related to the brand)

For question Q8 about the difference between the concepts of brand and goodwill, the informants were supposed to give their own answer and most of them agreed on the result that the difference lies primarily in the financial aspect since goodwill is actually intangible, however, the brand is tangible. The other most common answers were that they didn't know exactly, or that there is no fundamental difference. This implies that informants often cannot distinguish between these two concepts and tend to unite them in one.

Question Q9 further investigated whether, according to the informants, their company increases its goodwill value. Most informants (86%) answered yes, only 14% said they did not know. Figure 3 summarizes graphically the answers to Q10, Q11, and Q12. These questions investigated how often their company spends money to increase goodwill level by evaluating it on the 5-point Likert scale, where 5 represented the most frequently reported answer and 1 the least frequently reported answer. As goodwill includes both the enterprise and the personal dimensions, the questions were aimed at marketing (Q10), new technologies (Q11) and employee training (Q12).

Figure 3 shows that companies quite often spend resources on marketing communication and promotion (RII = 0.810), new technologies in the construction industry (RII = 0.781) and employee training (RII = 0.771). Only one company responded that it does not train employees at all and does not invest in new technologies (rating 1), however, it is very often active in marketing communications and promotion. These facts can be attributed to the fact that this is a micro company whose financial possibilities are likely to be very limited.

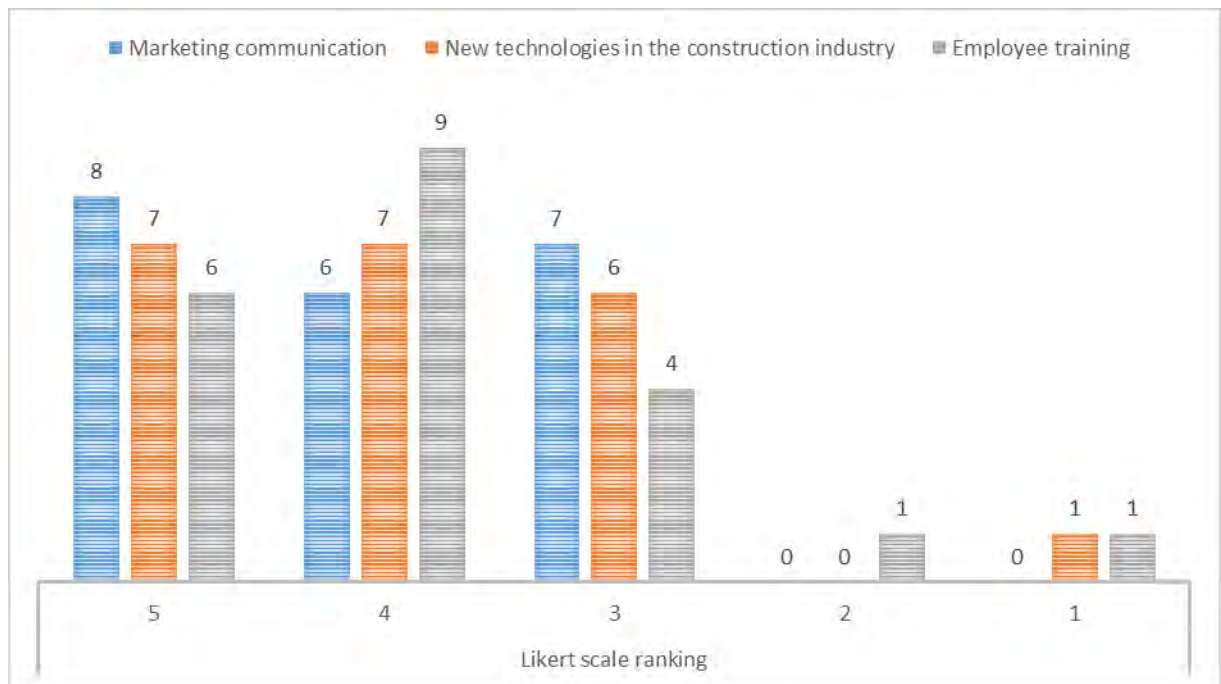


Figure 3. Absolute frequency of the evaluation of Q10, Q11, and Q12 questions on the 5-point Likert scale

#### 4.2 Interviews

The content of the interview was consistent in the thematic area with the questionnaire and was applied at one specific construction company. In total, 3 interviews were carried out with representatives of the company at the positions of director, managing director and construction engineer.

The first questions were focused on the issue of goodwill, where it was found out whether the company employees knew the concept of goodwill and what it meant according to them. Two of them did not know the concept and one said that goodwill, in his opinion, meant a good reputation of the company. Subsequently, the concept of goodwill was explained to all

interviewees in order to facilitate the successful completion of the interviews. After clarifying the concept, the question was whether goodwill was important for the company according to their opinion. Here all the interviewees were consistent and replied yes, for sure. Similarly, informants in the online questionnaire responded to this question confirming the claim that goodwill is very important nowadays and especially in the construction industry area where much more attention should be paid to it.

Other questions focused on the concept of brand, i.e. whether the interviewees know what the term means, and whether they could distinguish it from the concept of goodwill. Here, however, none of them was consistent in the answers and only one interviewee indicated that brand is a shortened company name which facilitates market orientation. However, neither interviewee could distinguish between the concept of goodwill and brand. According to one, the brand means business image and goodwill means good name, another interviewee saw the value of goodwill as a good reputation of a company and how people speak about it and concept of brand more in the financial sense. The last interviewee would connect both concepts in one and thought there was no difference. However, the brand is understood as a whole series of assets and liabilities of a company that is associated with the good name of the company and also with the brand symbol.

As to the question of whether interviewees know how a company increases its goodwill value, they agreed that it was primarily by quality work. According to the interviewees, the company did not spend sufficient funds on marketing promotion. However, it is not because they do not want to, but rather they want to focus on good reputation, positive references and, above all, on their approach to the work they carry out. In terms of investing in new technologies, the company was rather passive in this area, however it tried to train its employees on a regular basis, both through legal training courses and by its own initiative, which is very important in regards to the company goodwill.

## **5. Conclusion**

In this article, we have investigated the basic awareness about the issue of the goodwill, which Czech construction companies have. This issue is worthy of attention as proper perception and understanding of goodwill represents a significant support for correct decision-making relating to the acquisition of stake in companies.

Based on the analysis of both quantitative and qualitative data, it was found out that the vast majority of informants is aware of the importance of goodwill for their company, however in the context of understanding, it is important to note that concept of goodwill is not understood correctly enough. Above all, it is the fact that goodwill is only associated with a narrow view/factor in the eyes of informants, while goodwill represents a complex issue. In this context, it can be concluded that companies do not have a clear idea of how to effectively increase the value of company goodwill in its complexity. A similarly vague idea exists in the context of the distinction between the concept of brand and goodwill. It concludes that it would be advisable to make the professional public aware of the concept of goodwill, as increasing the value of a company is one of the basic goals and requirements of company owners nowadays.

The presented research has had limitations at several levels. It should be noted that the analysis carried out was based on a small sample of informants from the perspective of the questionnaire survey and on the representatives of only one construction company in terms of structured interviews. For this reason, the results of this initial study cannot be generalized, however it brings an interesting introductory insight into the issue being dealt with. The subsequent part of the research will focus mainly on the area of goodwill valuation methodology in the construction industry. The main motivation of follow-up research is to identify the factors affecting the value of goodwill substantially with respect to the specific feature of the construction industry. Future research outputs have the ambition to serve not only as a support to more accurate valuation of goodwill, but also in relation to achieving a long-term business goal, which is continuous increase of goodwill value in time.

## Acknowledgements

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# Quality, Environmental, Health and Safety Integrated Management System implemented into Construction Company

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## **Abstract:**

The QEHS and reliability of buildings, health and safety of all employees and keeping of all environment regulations on national and international level must be one of the most important factor of each construction company, which plans to be successful on world market. The development and successful implementation of Integrated Management System (IMS) focused to QEHS, environment, health and safety is not easy role, especially in bigger companies. During last 4 years were created new standards concerning the Quality Management Systems (ISO 9001:2015), Environmental management Systems (ISO 14001:2015), Occupational health and safety management systems (ISO 45001:2018), in which are defined requirements for implementation and certification of these management systems. All these standards has the same structure, which allows many processes in construction company integrated. This integration reduced required documented information and at the same time audited all processes in company departments and buildings. In my contribution will be described changes brought by new versions of higher described standards and analysed key processes concerning the development, implementation and continuing improvement of Quality, Environment, Health and Safety Integrated management Systems in construction company. Achievement of exceptional QEHS, environmental, health and safety level is now considered a necessity if an construction organization wants to succeed in a market in a hard competitive fight. Integrated Management System of all these three important factors mentioned in the contribution represents a significant tool for construction organization improvement effort and success on market.

*Keywords: Quality, environment, safety, management, system;*

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## **1. Introduction**

In the course of history, QEHS, environment, health and safety management has undergone a long development process. From self-control of own products (manufacturers of tools, craftsmen) through specialized controllers (manufactories and factories of the Industrial Age) to statistical control methods (influential pioneers: Ishikawa); from product QEHS to QEHS, environmental, health and safety of all business processes; from development of revolutionary philosophies, principles and methods (works of prominent QEHS experts: Deming, Juran, Crosby, to their worldwide acceptance in the form of stable, respected systems and defined standards: Total Quality Management - TQM, Quality, environmental, health and safety management systems according to ISO 9001, ISO 14001, ISO 45001 (Gasparik,J.& Gasparik,M), Kaizen, reengineering (Hammer & Champy), Six Sigma (Oakland), EFQM Excellence Model (Hakes).

Quality, environmental, health and safety management is part of management of the organization. The role of QEHS, environmental, health and safety management is to draw up and implement policies, principles and requirements for QEHS, environment, health and safety in the organization. It has four main components: QEHS, environment, health and safety (QEHS) planning, assurance, control and improvement.

QEHS management activities include for example data analysis, monitoring of performance and reliability of processes, recording achievement of goals, customer satisfaction analysis, etc. QEHS management pertains not only to products and services but also to company management and strategy.

Essential aspects of contemporary QEHS management include:

- strong management with a clear vision and policy of QEHS in the organization,
- effort to implement processes and their products correctly at first attempt,
- active involvement of all organization members in the QEHS improvement process and process of effective growth,
- customer and employee focus (product or service user, safety work place),
- implementation of a team-work system and self-control system,
- implementation of a system of incentives and bonuses for achieved results,
- continual process of employee trainings in the organization in QEHS.

In my contribution will be described changes brought by new version of international standards: ISO 9001:2015 (Quality), ISO 14001:2015 (Environment) and ISO 45001:2018 (Health and Safety) and effects of proposed Quality, Environmental, Health and Safety Integrated Management System (QEHS-IMS).

## **2. Changes brought by new version of ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018**

This chapter compares the current version of ISO 9001:2015, ISO 14001:2015, ISO 45001:2018 with the previous version of ISO 9001:2008, ISO 14001:2004 and OHSAS 18001:2008. It covers the main differences between these versions and deals with issues concerning validity of certificates obtained pursuant to the previous version of the international standards.

List of the most significant differences between the current and the previous version of ISO 9001, ISO 14001 and ISO 45001:

- All new standards has the same structure of chapters (see Figure 1)
- New standards does not contain the term preventive actions. Organizations are required to implement risk and opportunity management instead, which is covered in Chapter 6 Planning, subchapter 6.1 Activities to Handle Risks and Opportunities.
- A management review is no longer performed once a year but it has become a permanent component of the life of a corporation. In new standards, the management review is covered in Chapter 9 Performance Evaluation. New terms are considered:

performance, trend, alignment with the strategic direction of the organization, risks, influences and improvement opportunities.

- New standards no longer include a definition of the position of a Quality, Environment, Health and Safety Management Representative (QEHS-MR). The responsibilities and tasks of the QEHS-IMS are taken over by the management of the organization led by the director. However, in practice it will be possible to assign tasks related to the process of the QEHS-IMS implementation and maintenance to an employee and create a specialized position called e.g. QEHS coordinator of Integrated Management System (IMS).
- New standards do not oblige organizations to have a IMS Manual.

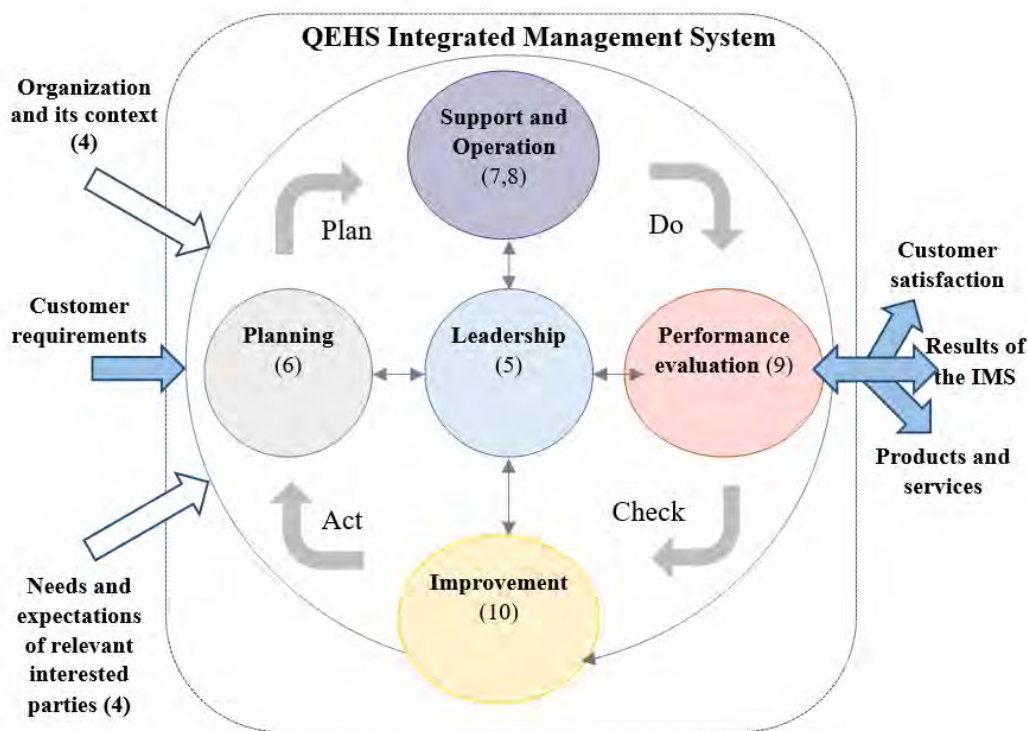


Figure 1. Structure of IMS according to ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 in PDCA cycle

- New standards do not recognize the terms document and record. It uses the term documented information instead. It is information that is required to be controlled and maintained by the organization and the medium on which it is contained.

New standards have now the same structure which allow to integrate their requirement into documented information and reduce it. You can see the structure of clauses of the current version of the standards in Table 1.

The International Accreditation Forum endorsed a three-year transition period from publication of the standards. The transition period is a period of time during which new or amended requirements under ISO 9001:2015, ISO 14001:2015, ISO 45001:2018 shall be implemented into existing management systems. The transition period of ISO 9001:2008 and



ISO 14001:2004 ended on 15 September 2018. At this time is valid only new standards ISO 9001:2015 and ISO 14001:2015. Previous standard for Health and Safety Management system OHSAS 18001:2008 is valid up to 13.03.2021 together with new standard ISO 45001:2018. After this datum will be valid only ISO 45001:2018 (Figure 2) and certificates of QEHS-IMS will be valid only according to new standards.

As compared to the previous version, the ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 standards contain more requirements. On the other hand, it provides more flexibility in meeting these requirements. The wording of the new standards can be seen as a step forward – they are transparent, they reflect the current situation in the business environment and their structure are practically the same and will be compatible with other new management systems. In addition to obtaining a certificate of QEHS-IMS, the standards can significantly contribute to achievement of higher efficiency and better business results of the organization in quality, environment, health and safety.

Table 1. Structuring of clauses of the current versions of the standards ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018

Clause	ISO 9001:2015, ISO 14001:2015, ISO 45001:2019
0	Introduction
1	Scope
2	Normative references
3	Terms and definitions
4	Context of the organization
5	Leadership
6	Planning
7	Support
8	Operation
9	Performance evaluation
10	Improvement



Figure 2. Transition period, validity of OHSAS 18001:2008 and ISO 45001:2018 certificate

## 2.1 Characteristics of ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018

International Organization for Standardization (ISO) issued ISO 9001:2015 and ISO 14001:2015 in year 2015, thus completing more than a three-year long review process in which 81 countries and experts from business, government, environment and academic sectors were involved. OHSAS 18001:2008 were by similar process replaced by standard 45001:2018. All new standards reflect the current situation in business and social environment. They also reflect contemporary phenomena such as globalization, the complexity of business environment, the existence of complex networks of supply chains as well as the growing importance of services. The objective in developing the new standards were to ensure a closer link between QEHS-IMS and overall corporate strategy, attempt to meet the needs of all stakeholders, take into account the context of the organization and provide a framework for integration of all three systems.

The most significant features of the current version of new standards include:

- Application of PDCA (Deming's) cycle (PDCA = Plan, Do, Check, Act) in the Integrated Management System) – see Figure 1.
- Compatibility of all new standards (see Table 1).
- Closer link to the general management system of the organization and to its strategic direction. The standards require greater involvement of top management in development of policies and goals concerning the quality, environment, health and safety.
- The current wording of the standards enable easier application also in organizations providing services.
- The requirements of the standards are less specific than expected when it comes to defining responsibilities and obligations.
- The standards require a closer alignment of the Integrated Management System with real operation of the organization in order to prevent bureaucratic approach to implementation of the Integrated Management System and perception of the System only as a tool to obtain the certificate.
- Implementation of a risk management system which will help the organization to identify risks and opportunities and define key priorities for operation of the organization.

All three new standards are based on a process approach which includes the PDCA cycle (Plan – Do – Check – Act) with risk-based thinking. The process approach enables organizations to plan their processes and their interactions. The PDCA cycle enables organizations to ensure that their processes are managed properly, have sufficient resources and define and implement improvement opportunities. Risk-based thinking enables organizations to identify factors which might cause that their processes and the Integrated Management System will divert from the planned results and to take effective management actions in order to minimize negative impact and maximize use of opportunities if they arise. The process approach requires systematic definition and management of quality,

environmental, health and safety processes and their interactions so that the intended results can be achieved in line with management and strategic direction of the organization.

Application of the process approach in the Integrated Management System enables: understanding and consistency in meeting requirements, consideration of the added value of processes, achievement of efficient performance of processes and improvement of processes based on data and information evaluation.

## 2.2 Documented information of Integrated Management System

The requirements for documented information are contained in Clause 7 Support, Section 7.5 Documented Information and are divided as follows:

- General Requirements,
- Creating and Updating,
- Control of Documented Information.

IMS shall include:

- documented information required by new international standards,
- documented information determined by the organization as being necessary for the effectiveness of the IMS. The extent of documented information depends on the size and type of the organization, complexity of processes and their interactions and on competence of persons.

When creating and updating documented information, the organization shall ensure appropriate:

- Identification and description (e.g. a title, date, author, or reference number),
- format (e.g. language, software version, graphics) and media (e.g. paper, electronic),
- review and approval for suitability and adequacy.

Documented information required by the IMS and by these international standards shall be controlled to ensure:

- it is available and suitable for use, where and when it is needed,
- it is adequately protected (e.g. from loss of confidentiality, improper use, or loss of integrity).

For the control of documented information, the organization shall address the following activities, as applicable:

- distribution, access, retrieval and use,
- storage and preservation, including preservation of legibility,
- control of changes (e.g. version control),
- retention and disposition.

If documented information of external origin exists, the organization shall identify and control it as appropriate. Documented information retained as evidence of conformity shall be protected from unintended alterations.

Clauses 4 to 10 of all new standards contain several requirements obliging the organization to document certain information. Some of these requirements shall be met by the organization under all circumstances (e.g. to draw up a Quality, Environmental, Health and Safety Policy), others are linked to specific situations (e.g. to document an incident if property, customers or external providers are damaged).

The following Table 2 lists all obligations regarding documented information under the current new standards arranged according to clauses of the standard.

If the standard refers to “information“(without mentioning an obligation regarding documenting of information) – for example in Clause 4.1 “the organization shall monitor and review information about these external and internal issues“ – there is no obligation to document this information. In this case, the organization may decide whether it is necessary or appropriate to maintain the documented information or not.

### 3. Modification of EFQM excellence model into QEHS-IMS

The EFQM excellence model was developed by the European Foundation for Quality Management with the aim to provide a single structured framework for self-evaluation of performance of the organization and to introduce a versatile quality management tool for seeking possibilities of continual improvement of the construction organization on its road to excellence. Nationwide recognition of quality in the USA (Malcolm Baldrige National Quality Award) and in Japan (Deming Prize) revealed the fact that application of TQM models brings measurable business results to organizations. The EFQM Model is one of TQM models (HAKES, C. (2007).

The EFQM Model constitutes a basis for assessment and evaluation of businesses aspiring to the European Quality Award (EQA) and to the National Quality Award. The EQA requires application of the model for at least three years and ability to demonstrate corresponding results.

The EFQM Model can be applied in any organization in the business sector as well as in public administration (however, the Common Assessment Framework (CAF) is intended primarily for public administration). Nowadays, many companies use this model as their internal methodology to measure their own performance.

Table 2. Mandatory documented information (DI) stated in the clauses of ISO 9001:2015, ISO 9001:2015, and ISO 45001:2018

Clause 4 Context of the organization		
Subclause	Type of documented information	Description
4.3	maintained	Scope of the IMS, types of products and services covered.
4.4.2	maintained	DI to the extent necessary, to support the operation of its processes.
4.4.2	retained	DI to the extent necessary, to have confidence that the IMS processes are being carried out as planned.
Clause 5 Leadership		
5.2.2	maintained	Quality, environmental, health and safety policy.
Clause 6 Planning		
6.1.1	retained	Quality, environment, health and safety risks (determination and addresses) and opportunities
6.1.3	retained maintained	Determination of legal and other requirements concerning the quality, environment, health and safety

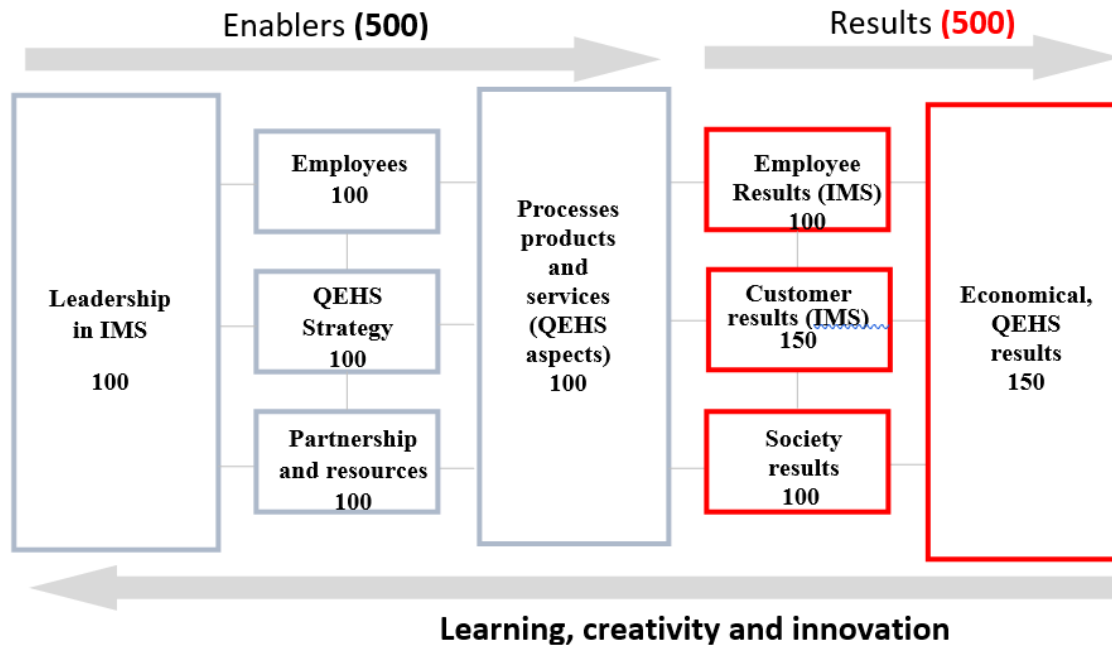
6.2	maintained	Quality, environment, health and safety objectives.
<b>Clause 7 Support</b>		
7.1.5.1	retained	Monitoring and measuring resources - evidence of suitability.
7.1.5.2	retained	In case of using own basis for calibration – retain it as DI.
7.2	retained	Evidence of personal competence.
<b>Clause 8 Operation</b>		
8.1	maintained retained	Organization determine, maintain and retain documented information to the extent necessary: - to have confidence that the processes have been carried out as planned, - to demonstrate the conformity of products and services to their requirements.
8.2.3.1	retained	Requirements not stated by customer.
8.2.3.2	retained	Applicable retained DI about: results of the review (of requirements for products and services), any new requirements for the products and services.
8.2 (ISO14001) 8.2. (ISO 45001)	retained maintained	Emergency preparedness and response in environment area  Emergency preparedness and response in health and safety area
8.3.2	retained	Demonstration that design and developments requirements have been met.
8.3.3	retained	Design and development inputs.
8.3.4	retained	Design and development controls.
<b>Clause 8 Operation</b>		
8.3.5	retained	Design and development outputs.
8.3.6	retained	DI about: - design and development changes, - the results of reviews (of design and development changes), - the authorization of the design and development changes, - the actions taken to prevent adverse impacts.
8.4.1	retained	DI about: - controls applied on processes, products and services provided from external providers, - determining and applying criteria for the evaluation, selection, monitoring of performance and re-evaluation of external providers(suppliers), - actions arising from the evaluations.
8.5.1	available	The characteristics of the products to be produced, the services to be provided, or the activities to be performed. The results to be achieved.
8.5.2	retained	DI to enable traceability of the outputs, when traceability is a requirement.
8.5.3	retained	DI related to an event, when the property of a customer or external provider is lost, damaged or otherwise found to be unsuitable for use.

8.5.6	retained	Organization shall retain DI describing: - the results of the review of changes (related to production or service providing), . the person(s) authorizing the change, and any necessary actions arising from the review.
8.6	retained	DI about release of products and services.
8.7.2	retained	DI about nonconformity (description of nonconformity, actions taken, concessions obtained, authority deciding the action in respect of the nonconformity).
<b>Clause 9 Performance evaluation</b>		
9.1.1	retained	Evidence the results of evaluation of the IMS performance and its effectiveness.
9.2.2	retained	Evidence of the implementation of the internal audit programme and the internal audit results of IMS
9.3.3	retained	Evidence of the results of the IMS management reviews.
<b>Clause 10 Improvement</b>		
10.2.2	retained	Nonconformity and corrective action – to retain DI about: - nature of the nonconformities, - actions taken, - results of corrective actions.

EFQM was first introduced in 1991 as the European Model for Business Excellence. In 1999, it was innovated and became more versatile and applicable in more organizations. The Common Assessment Framework (CAF) was developed for the public administration sector. It was introduced in 2000 and reviewed in 2002.

The EFQM model can be implemented also into Quality, environmental, health and safety integrated management system (QEHS-IMS) In Figure 3 are defined main criteria for QEHS-IMS. In recent years, minor revisions are made regularly in the EFQM Model, concerning in particular names and definitions of the criteria and the points that can be obtained for each criterion. The QEHS-IMS Excellence Model is based on nine criteria. The first five criteria are Enablers (what the organization has), the other four are Results (what the organization achieves). Each criterion is further divided into sub-criteria – altogether there are 32 sub-criteria. The scheme of the QEHS-IMS Excellence Model and the points that can be obtained for each criterion can be seen in Figure 3. The direction of the arrows shows the dynamic nature of the model. Learning, creativity and innovation help to improve Enablers which then lead to improvement of Results. This process is constant.

Achievement of a higher quality, environmental, health and safety level and economic prosperity of the construction organization are not the only benefits of the QEHS-IMS Excellence Model. It encourages application of approaches in line with moral and ethical values and principles of responsibility. It also encourages organizations to come up with a vision including these values and leads to responsibility towards the society as a whole – environment, region, etc., emphasizing positive public image of the organization.



**Figure 3. EFQM model scheme implemented into QEHS-IMS Excellence Model with the score for the criteria**

Based on the knowledge in the field of quality, environment, health and safety management gained from literature and from practical experience, the following main benefits of the QEHS-IMS Excellence Model and its application in the organization can be formulated: complexity, versatility, excellence as a goal, possibility of self-evaluation, compatibility with ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 standards, European and global dimension, flexibility in application, integration of improvement methods and systems, links to quality, environmental, health and safety awards.

The Deming PDCA cycle and comparison with industry leaders are useful tools in application of the EFQM Model methodology and self-evaluation. Although the European excellence model is not new, our survey clearly shows that its application in practice is still not common, mainly because of low awareness of the benefits of application of this model in practice and concerns of corporate managements about time and resource requirements for implementation of the model. In the past, organizations implemented the model chiefly with the aim to win a quality award but our findings show that the QEHS-IMS Excellence Model can be used also as an important internal tool for evaluation and complex continual improvement of quality, environment, health and safety of the organization at all levels.

#### **4. Conclusion**

This contribution analyses the most significant requirements of new management systems in quality, environment, health and safety area for in construction company. The Integrates Management System according to actual standards ISO 9001:2015, ISO 14001:2015 and ISO 45001:2018 can increase credibility in the eyes of customers and other business entities and boosts chances of being successful in tenders. The organization itself benefits from it in the form of higher effectiveness, savings and process optimization. The IMS constitutes a system

which should ensure and standardize quality, environmental, health and safety procedures in the organization. Some of them are obligatory and required by regulations, others can be defined by the organization itself and the IMS can be used to document, monitor and control them and assess their success rate. Organizations aiming to grow and progress in the field of quality, environment, health and safety can benefit from the IMS as well. The IMS is a strong pillar for application of higher quality, environment, health and safety management forms such as TQM, Kaizen, Reengineering and QEHS-IMS Excellence Model.

Total Quality Management (TQM) and Kaizen focus on gradual and sustained improvement of quality of products and processes and they represent a superstructure of the implemented Integrated Management System and are highly compatible with its principles. Reengineering is a fundamental rethinking of existing processes in the organization and focuses on innovation of Quality, Environmental, Health and Safety processes and achievement of extraordinary effects.

The QEHS-IMS Excellence Model is universally usable also as an great internal tool for company's self-evaluation of QEHS-IMS and for comprehensive, continuous improvement of organization on all levels. In my consultancy activity on implementing QEHS-IMS and applying QEHS-IMS Excellence Model as a means of continuously improving QEHS-IMS efficiency, after a year of application of this model of excellence the efficiency of construction organization QEHS-IMS has increased by an average of 30%.

Achievement of exceptional quality, environment, health and safety is now considered a necessity if an construction organization wants to succeed in a market in a hard competitive fight. QEHS-IMS Excellence Model mentioned at this contribution represents a significant help for organizations in this effort. It is a long-term process, which begins with great strategic decision and continues as persistent, purposeful attitude of management and all the people participating on construction company's life. This paper was prepared during research work at scientific project VEGA N. 1/0511/19

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