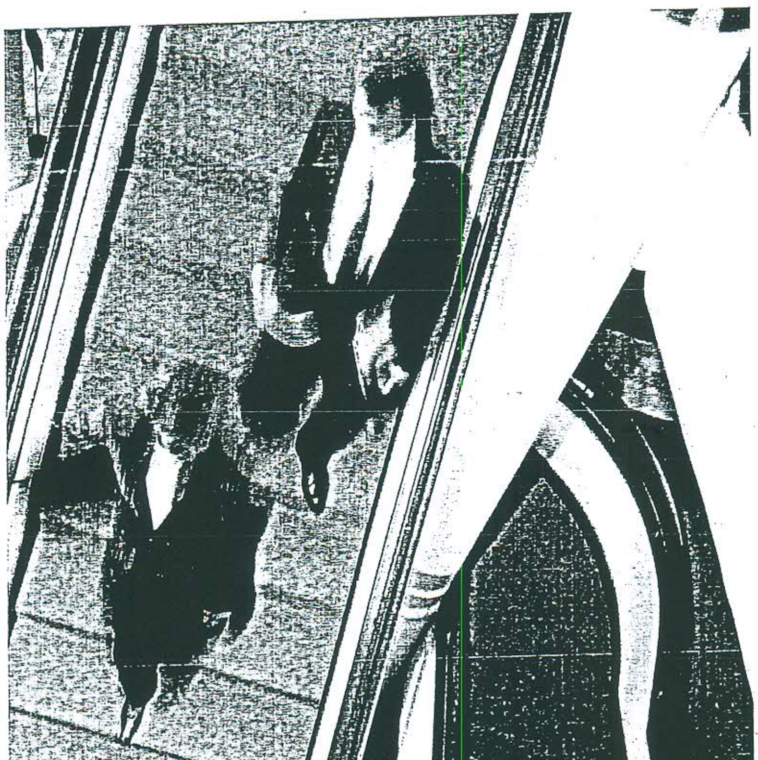
NFPA READY REFERENCE

# Human Behavior in Fire Emergencies



NFPA®

*NFPA Ready Reference*

# Human Behavior in Fire Emergencies

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# Contents

# Preface

*NFPA Ready Reference: Human Behavior in Fire Emergencies* is a compilation of material for those who are looking for the latest specialized information on human behavior in fire emergencies. The material is varied and comes from an assortment of sources, such as NFPA's *Fire Protection Handbook,* the *NFPA Journal,* and NFPA's fire investigation reports. The selection of information was based on the idea that this material would be useful to engineers, engineering students, architects, business and industry safety personnel, and fire and life safety educators who need a reference book that pulls together in one place recent facts and figures on this subject.

Part I provides statistical information and an overview of human behavior in fires. Selection 1, "Human Behavior and Fire," Selection 2, "Calculation Methods for Egress Prediction," and Selection 3, "Concepts of Egress Design," originally published in the 2003 edition of NFPA's *Fire Protection Handbook,* offer information and statistics for planning how people will react when faced with an emergency fire situation.

Selection 4, "Occupant Response to Fire Alarm Signals," was originally published in NFPA's 2002 edition of the *National Fire Alarm Code Handbook* and provides information on how people react when a fire alarm sounds and they're faced with a potential emergency situation.

Part II presents articles published in the *NFPA Journal.* Selection 5, "Security Bars Can Have Unintended Consequences," explains how the security bars on doors and windows that are used to keep intruders out can also trap people inside during a fire and how making a simple alteration to those bars and learning correct fire safety behavior can make all the difference in a fire emergency. Selection 6, "The Human Factor," reviews how human behavior emerged as a key element to life safety in the September 11, 2001 attack on New York City's World Trade Center. Selection 7, "Human Element Key to Safety Program," looks at how staff training is a main element to fire safety in health care facilities. Selection 8, "Panic Is a Misunderstood Concept," looks at how, surprisingly, *lack* of panic characterizes human behavior during many fires.

Selection 9, "Safety in Numbers," details how the standards-making community uses incident investigations and behavior research to determine how crowds actually behave during an emergency and then designs systems to reinforce that behavior. Selection 10, "Evacuation," details NFPA's plans to revisit their previous World Trade Center behavior report with an evacuation behavior follow-up. Selection 11, "What Went Wrong?" explains how lack of basic fire safety knowledge can lead to fatal mistakes in human behavior. Selection 12, "How Cognitive Factors Influence Way-Finding," discusses how emergency egress design limitations influence the egress performance of buildings.

Part III offers an in-depth look at human behavior in Selection 13, which presents several case studies that were originally published in the Firewatch section of the *NFPA Journal,* a human behavior study from the 1993 bombing of New York City's World Trade Center in Selection 14, and a fire investigation report from NFPA on the bombing.

NFPA has extensive additional material on the topic as well. This includes several human behavior studies on such fires as the MGM Grand Hotel fire and the Beverly Hills Supper Club fire. There are also several *NFPA Journal* articles on the subject, such as the upcoming article on sleeping children and smoke alarms, the 1994 article entitled, "Who Died in Fires in the United States?," the 1993 article, "Leaving Children

Unsupervised Is Playing with Fire," the 1989 article, "How Being Poor Affects Fire Risk," and the 1986 article, "Fatal Fires and Unsupervised Children." The material selected for this book, however, is intended to serve as a compilation of the more recent information from NFPA on this topic.

# PART I
# OVERVIEW AND STATISTICS

*Part I provides general information on human behavior in fires and offers details and statistics for planning how people will react when faced with an emergency fire situation.*

# SELECTION 1

# Human Behavior and Fire

**John L. Bryan**

*This selection, reprinted from the 2003 edition of NFPA's* Fire Protection Handbook, *offers information and statistics for planning how people will react when faced with an emergency fire situation. All internal cross references, figure numbers, and table numbers remain unchanged and refer to the original published material.*

*Source:* Section 4, Chapter 1, *Fire Protection Handbook,* 19th Edition, 2003.

# CHAPTER 1
# Human Behavior and Fire

*Revised by*
John L. Bryan

London fire

How one reacts during a fire is related to the role assumed, previous experience, education, and personality; the perceived threat of the fire situation; the physical characteristics and means of egress available within the structure; and the actions of others who are sharing the experience. Postevent analysis of behavior has described actions as adaptive or nonadaptive, participative or inhibited, and altruistic or individualistic. Detailed interview and questionnaire studies over the last half century have established that instances of nonadaptive- or panic-type behavior are rare, occurring under specific conditions. Most behavior in fires is determined by information analysis, resulting in cooperative and altruistic actions.

The earliest documented studies on human behavior in the United States involved capacity counts of the velocity of pedestrian movement for the New York city design of the Hudson Terminal Building in 1901.[1] The first edition of the National Fire Protection Association's *Building Exits Code* in 1927 was developed from evacuation studies conducted during the decade since 1917.[2] Classical evacuation studies involving railway terminals, subway stations, theaters, department stores, and federal government office buildings with both "normal" exiting flows and "fire-drill" exiting flows were conducted in the early 1930s and published in 1935.[1]

In England, the London Transit Board and other evacuation studies were conducted.[3,4] In the United States, during the 1940s and the 1950s, a lack of interest in studies on human behavior in a fire was prevalent, even in fires that resulted in large loss of life, such as the Cocoanut Grove fire, in which dedicated human behavior studies of the activities of the occupants were not conducted. An exception was the interview study of selected occupants of the Arundel Park fire in 1956, which verified the process of reentry behavior by members of family groups.[5] The most productive period for research and publications in the United States on human behavior appeared to be from 1970 through the mid-1980s. The five-year study and report of the National Commission on Fire Prevention and Control, entitled *America Burning,* in 1973 provided a federal government focus on the national fire problem.[6] This report resulted in new and enhanced federal financial support for all facets of fire research including human behavior, even though the report envisioned the role of human behavior research being primarily applicable to the educational aspects of fire prevention. During the 1970s the National Bureau of Standards, through the Center for Fire Research, and the National Fire Protection Association were the primary sources for funding studies on human behavior in fire in the United States. Thus, studies resulted in an examination and development of the methods for investigating behavior of the occupants in fire situations in both the United States and United Kingdom. Funding was also provided for the formation with Japan of the United States and Japan Natural Resource Panel on Fire Research and Safety, which included the study area of human behavior in fire.[7–15]

The emphasis of the studies in human behavior in fire during this period was on defining the behavioral actions of the occupants in fire situations, the examination of the then popular concept of "panic behavior," and an emphasis on the study of the evacuation process as it occurred in high-rise building fires.

Characteristics of the behavior of people individually and within groups have been determined primarily by research studies in which individuals were interviewed by fire department personnel at the time of the fire.[8,15] It must be recognized that an individual's behavior in a fire is affected by the variables of the building in which the fire occurs and by the appearance of the fire at the time of detection. For example, the occupants' response will vary if they smell smoke rather than see flames or dark, acrid smoke completely obscuring a corridor. Variables of the fire protection provided for the building may also be critical to the individual's perception of the threat involved. Obviously, the most important individual decisions and behavior in life-threatening situations occur before the arrival of the fire department, in the early stages of the fire. Studies of healthcare facilities have indicated the importance of this early behavior:

> In the process of investigating these case studies we have come to believe that the period between detection of the fire and the arrival of the fire department is the most crucial lifesaving period in terms of the first compartment (the area in direct contact with the room of origin and the fire).[12]

Thus, the behavior of the individuals intimately involved with the initiation of the fire is critical not only for themselves but often for other occupants of the building. It should be recognized that the altruistic behavior observed in most fires with the interaction of the occupants and the fire environment in a deliberate, purposeful manner appears to be the general mode of

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reaction. The nonadaptive flight or panic-type of behavioral reaction is apparently unusual in fires.

## AWARENESS OF THE FIRE

Obviously, the way in which an individual is alerted to the presence of a fire may determine the degree of threat perceived. With vocal alerting systems in buildings, variations in voice quality, pitch, or volume, as well as the content of the message, tend to provide threat cues.[16]

Proulx and Sime[17] in their study involving evacuation drills in an underground rapid transit station found the use of directive public announcements with an alerting alarm bell most effective in creating an immediate effective evacuation. Ramachandran in his review of the research on human behavior in fires in the United Kingdom since 1969 summarized the effectiveness of alarm bells as awareness cues: "The response to fire alarm bells and sounders tends to be less than optimum. There is usually skepticism as to whether the noise indicated a fire alarm and if so, is the alarm merely a system test or drill?"[18]

Ramachandran[19] indicated that the development of "informative fire warning systems," which use a graphic display with a computer-generated message and a high-pitched alerting tone, has reduced the observed delay times in the initiation of practice evacuations. Cable[20] in his study of the response times of staff personnel to the fire alarm signal in veterans administration hospitals found the greatest delay in response time with the coded alarm-bell type systems. Kimura and Sime[21] in a study of the evacuation of two lecture halls with college students found that the lecturer's verbal instructions were the determining factor in the students choosing to use the fire exit over the normal entrance and exit. Research literature developed from practice evacuations indicates that the use of verbal directive informative messages may be most effective in reducing delay in evacuation initiation.

However, note that if verbal directive messages conflict with other awareness cues, such as the odor or sight of smoke, occupants may question the credibility of the message and disregard the information. One of the few documented cases of this type of situation occurred in the South Tower of the World Trade Center on April 17, 1975. Lathrop[22] reported that the fire occurred in a trash cart in a storage area on the fifth floor, adjacent to an open stairway door that allowed smoke to infiltrate the ninth through twenty-second floors at approximately 9:04 a.m. Occupants of these floors moved into the core area of the building, and the building communications center monitoring the core lobby areas verbally directed the people in these areas to remain calm and return to their office areas at 9:10 a.m. Despite this announcement, occupants remained in the core lobby areas and became more concerned about smoke conditions. Thus, with occupants on the affected floors becoming more anxious, an evacuation message was announced at 9:16 a.m.

As Burns[23] reported, simultaneous occupant evacuations occurred in the explosion and fire of February 26, 1993, which severely affected both towers and the Vista Hotel of the World Trade Center. The explosion disrupted the Center's communications center, and the occupants, having experienced within minutes the explosion, loss of power and smoke infiltration of the floors areas, evacuated without the established verbal directional announcements used in previous practice evacuations.

Fahy and Proulx[24] in their questionnaire study of 382 trained fire warden personnel located in both towers of the World Trade Center at the time of the explosion and fire of February 26, 1993, found these personnel were alerted primarily in the following manner:[24]

> Respondents mentioned the following cues, either singly or in combination that something was occurring: hearing or feeling the explosion, loss or flickering of lights or telephones, smoke or dust, sirens and alarms, information from others, and people movement.

Most of the participants in residential occupancy studies were alerted initially to the fire by the odor of smoke. When the two categories "notified by family" and "notified by others" are combined, however, personal notification becomes the most frequently reported means of initial perception of fire, as indicated in Table 4.1.1.[8] The category "noise" includes noise from persons moving downstairs and through corridors, plus miscellaneous noise sources, including the breaking of glass and the arrival of fire apparatus.

Table 4.1.2 compares the means of awareness from participants of a British study[15] and those of a U.S. study.[8] The number of stimuli was reduced because the British study had fewer categories, and the U.S. responses have been adapted to the British categories. There was only one significant difference in the means of awareness between the two groups: 15 percent of the British participants became aware of the fire upon observing flame, contrasted with 8.1 percent of the U.S. participants.

A study of the NFPA-recommended smoke detector noise level of 75 dBA indicates that individuals with hearing impairments, those taking sleeping pills, or those on medication may require a detector noise level exceeding 100 dBA[25] (see *NFPA 72®, National Fire Alarm Code®*). Flashing or activated lights are effective fire signals in occupancies populated primarily by hearing-impaired persons.[26] The 1981 edition of NFPA *101®, Life Safety Code®* for the first time permitted flashing of exit signs along with activation of an audible fire alarm system.

**TABLE 4.1.1** *Means of Awareness of the Fire Incident (United States Studies)*

| Means of Awareness | Participants | Percent |
|---|---|---|
| Smelled smoke | 148 | 26.0 |
| Notified by others | 121 | 21.3 |
| Noise | 106 | 18.6 |
| Notified by family | 76 | 13.4 |
| Saw smoke | 52 | 9.1 |
| Saw fire | 46 | 8.1 |
| Explosion | 6 | 1.1 |
| Felt heat | 4 | 0.7 |
| Saw/heard fire department | 4 | 0.7 |
| Electricity went off | 4 | 0.7 |
| Pet | 2 | 0.3 |
| *N* = 11 | 569 | 100.0 |

**TABLE 4.1.2** *Comparison of British and United States Study Results Relative to Means of Awareness of a Fire Incident*

| Means of Awareness | British (percent, $P_1$) | U.S. (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1-P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| Saw flame | 15.0 | 8.1 | 6.9 | 1.64 | 4.21[c] |
| Smelled smoke | 34.0 | 35.1 | 1.1 | 2.27 | 0.48 |
| Heard noises | 9.0 | 11.2 | 2.2 | 1.41 | 1.56 |
| Heard shouts and was told | 33.0 | 34.7 | 1.7 | 2.25 | 1.20 |
| Heard alarm | 7.0 | 7.4 | 0.4 | 1.23 | 0.33 |
| Other | 2.0 | 2.8 | 0.8 | 0.70 | 1.14 |
| $N = 6$ | 2193 | 569 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratio (CR) significant at or above the 1 percent level of confidence.

A study of 24 male subjects that was designed to determine whether they were awakened by a smoke detector's audible alarm signal and could identify fire cues found that the subjects slept through the alarm signals at a signal-to-noise ratio of 10 dBA and consistently failed to identify the awakening cue or radiant heat and smoke odor cues as fire warnings.[27] Other researchers have indicated that the alarm-signal-to-noise ratio is attenuated by physical surroundings.[28] A signal passing through a ceiling or a wall may be reduced by 40 dBA, whereas a signal passing through a door may be reduced by 15 dBA; in addition, the signal could be masked by a typical residential air conditioner noise level of 55 dBA.

The acknowledgment of ambiguous threat cues as signaling an emergency may be inhibited by presence of other people. Recognition of this phenomenon resulted in an experiment involving college students.[29] While the students were completing a written questionnaire, the experimenter introduced smoke into the room through a small vent in the wall. If the students left the room and reported the smoke, the experiment was terminated. If the students did not report the presence of the smoke within 6 min from the time they first noticed, the experiment was considered complete. Students alone in the room reported the smoke in 75 percent of the cases. When two passive, noncommittal persons joined each student, only 10 percent of the students reported the smoke. When the experimental group consisted of three naive subjects, one individual reported the smoke in only 38 percent of the groups. Of the 24 persons involved in the eight naive-subject groups, only one reported the smoke within the first 4 minutes of the experiment. In the single-subject situation, 55 percent of the subjects reported the smoke within 2 min and 75 percent in 4 min.

The study reported that reaction to smoke was apparently delayed by the presence of other persons, with the median being 5 s for single subjects but 20 s in both the group conditions. These results undoubtedly reflect constraints that people accept regarding their behavior in public places. The performance of naive subjects in the passive-confederate situation was reported as follows:

> The other nine stayed in the waiting room as it filled up with smoke, doggedly working on their questionnaires, and waving the fumes away from their faces. They coughed, rubbed their eyes, and opened the window but did not report the smoke.[29]

It has been suggested that while trying to interpret the emergency potential of ambiguous threat cues, an individual is influenced by the reactions of others. Should these others remain passive and seem to interpret the situation as a nonemergency, the individual tends to modify his or her own interpretation according to this inhibiting social influence.[29] This behavioral experiment may help explain the reported tendency of people to disregard threat cues or interpret them as nonthreatening when they occur in places where there are many other people, such as restaurants, movie theaters, or department stores. These results may help explain the calls received by fire departments minutes or even hours after an incident is first detected. In the report of the Arundel Park fire,[5] several of the sample population indicated that when they entered the hall after observing the fire from outside the building, they warned their friends and suggested they leave but were laughed at, their warnings apparently disregarded.

Social inhibition, diffusion of responsibility, and mimicking have been indicated to be primarily responsible for the inhibition of adaptive and assistance behavior in emergencies. The inhibition of behavior in the early stages of a fire, when the cues are relatively ambiguous, may lead to nonadaptive flight behavior because the time available for evacuation has been expended. It is sometimes difficult to get the occupants of a building to evacuate because of social inhibition and diffused responsibility. The tendency to adopt cues for behavior from others is well documented in fires in restaurants, other public assembly occupancies, and hotels.

## DECISION PROCESSES OF THE INDIVIDUAL

Seven processes have been identified that an individual may use in trying to structure and evaluate situational threat cues.[30] Six of these—recognition, validation, definition, evaluation, commitment, and reassessment—are presented in Figure 4.1.1. The seventh, a lattice involving the failure of successive defensives and a hierarchy of defenses, is not relevant to the decision process in fires.

### Recognition

Recognition occurs when the individual perceives cues that indicate a threatening fire. The cues may be very ambiguous and not clearly indicative of a severe fire. However, the clues usually are continuous, with an increasing intensity due to the dynamics of flame, heat, and smoke production. It was also reported that an individual is predisposed to recognize threat cues in terms of the most probable occurrences, usually in relation to past experience and in the form of an optimistic wish. The optimistic wish aspect

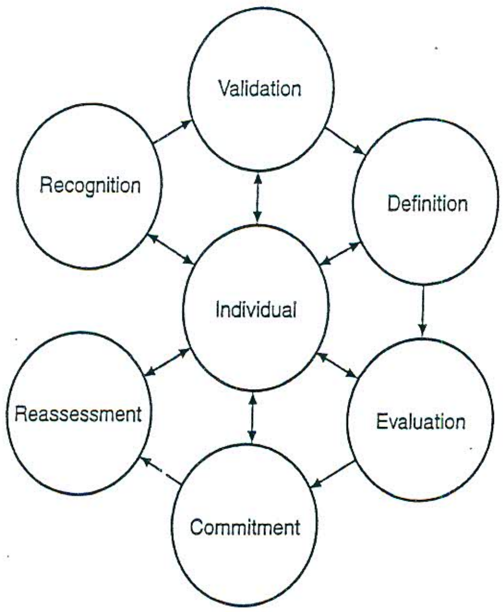


**FIGURE 4.1.1** *Decision Processes of the Individual in a Fire*

of the response may be a direct result of the individual's concept of his or her personal invulnerability.[30]

Threat recognition is important for fire protection. The adaptive action involved in the initiation of the fire alarm, the evacuation of building occupants, and the suppression of the fire may be delayed or postponed if individuals do not perceive the cues as indicative of a fire. The ambiguous nature of threat cues indicates that individuals who do not have specialized fire prevention or fire protection education and experience recognize only large amounts of smoke or sudden and threatening flames as indicative of a threatening fire.

## Validation

Validation consists of attempts by an individual to determine the seriousness of the threat cues, usually by reassurance of the mild nature of the threat and its improbability. When the cues are significantly ambiguous, however, the individual tries to obtain additional information. In other words, the person is aware that something is happening but is not sure exactly what. This process of validation may be conducted by questioning other nearby individuals. Studies of the explosion of a fireworks plant in Houston, Texas, found that of the 139 persons interviewed, 85 individuals (or 61 percent of the population) obtained information on the source and nature of the explosion and smoke from someone they saw or from someone who telephoned and told them.[31] The presence of others during the threat recognition and validation process was found possibly to inhibit or influence the behavioral responses of the individual.

## Definition

Definition essentially consists of an attempt by the individual to relate the information concerning the threat to some of the variables, such as the qualitative nature of the threat, the magnitude of deprivation of the threat, and the time context. The individual's stress and anxiety appear to be most severe before he or she has determined the situation's structure or meaning, although it is apparent that the situation requires interpretation. The individual's role (described at the end of the Evaluation section) is one of the critical factors in the situation, relative to the personalization of the threat and the physical environment. The most important physical aspects in the definition process are the generation, intensity, and propagation of the smoke, flames, and thermal exposure.

## Evaluation

Evaluation may be described as the cognitive and psychological activities required for the individual to respond to the threat. The individual's ability to reduce his or her stress and anxiety levels becomes the essential psychological factor. In the threat situation created by a fire, evaluation is the process involved in the decision to react by fight or flight. With evaluation, an initial decision to make an overt behavioral response is completed. Because of the time context of the generation and propagation of the fire, the mental processes up to and including the process of evaluation may have to be accomplished within several seconds.

Sime[32] emphasized the importance of the individual's perception of the time available for evacuation or to reach a refuge area as being the individual's estimation of the fire threat. He indicates that the "perceived time available" depends upon the information and communication provided to the occupants concerning the fire's location and development. Variables of the physical environment are an important source of information for individuals involved in formulating adaptation, escape, or defense plans. Additional determinants may be the location of the individual relative to the egress routes, other people, the untenable effects of the fire, and the behavior of other individuals.

During evaluation, an individual may decide to leave the building—flight—or to use a portable fire extinguisher—fight. During this time, he or she is particularly susceptible to the actions and communications of others. Thus, the individual may mimic the behavioral reactions of observed individuals, resulting in mass adaptive or nonadaptive behavior rather than selective, individualized behavior. The following situation at an auto sales and service agency in 1971 demonstrates what may have been an instance of mimicked behavior becoming normative group behavior:[33]

> About 10 pm, the fire department received an alarm from a street fire alarm box. When fire fighters arrived, the 150 by 200 ft (46 by 61 m), one- and two-story building of wood frame and hollow block construction was well alight and nearly 300 spectators were watching the fire in 10°F (–12°C) weather. An investigation revealed the fire had been burning for about 90 minutes before the fire department was notified.

In studies of nonadaptive group behavior, the concept that this mode of behavior depends directly on the individual's perception of the reward structure of a situation has been developed.[34] People in a building who are confronted with a fire would probably initially perceive a reward structure that would encourage cooperative and adaptive behavior; in such cases, everyone should be able to reach and proceed through the available exits. However, the reward structure perceived by some individuals more remote from the egress routes could result in competitive behavior. Such individuals would perceive that cooperative behavior would make it impossible for them to reach an exit in time to escape the fire. Once the pattern of competitive behavior is initiated, the behavior pattern of the group may become one of intense individual competition for the escape routes.

In the evaluation process, an individual's cultural influences and assumption of a particular role may be very important in formulating defense or escape plans. It is believed that an individual playing a familiar role that is also suitable for the threat situation experiences less anxiety and responds with more adaptive behavior than an individual in an unfamiliar role confronted with an unfamiliar threat.

Jones and Hewitt[35] conducted detailed interviews with 40 occupants of a 27-story office building who had evacuated the building during a fire. It should be noted the fire occurred at 9:00 p.m. when the fire management plan was not in effect due to the building's reduced occupancy. In this situation it appeared that leadership and evacuation group formation were related to the occupants' fire training and their normal roles. The investigators found that relationship of the occupancy roles and normal or emergent leadership of occupants were critical factors in successful evacuation, with the following variables:

> The social and organizational characteristics of the occupancy, including what a person knows (or believes) of the situation, whether the person is alone or part of a group, the normal roles that people hold within the occupancy, and the organizational structure or framework. One factor that appears to be related to the chosen evacuation strategy of an occupant is the presence of leadership and the form which that leadership takes.

Horiuchi, Murozaki, and Hokugo[36] reported on a questionnaire study of 458 occupants of an eight-story office building involved in a fire incident. The researchers found significant differences between occupants who were familiar with the building and occupants attending training sessions who were unfamiliar with the building, relative to their actions, selection of evacuation routes, and effectiveness in exiting. The regular occupants of the building engaged in fire-fighting actions and alerted or assisted other occupants, while occupants unfamiliar with the building primarily engaged in evacuation.

## Commitment

Commitment consists of the mechanisms the individual uses to initiate the behavioral activity required to fulfill the defense plans conceptualized in the evaluation process. This overt response to the threat of fire results in success or failure. If the response fails, the individual immediately becomes involved in the next process of reassessment and commitment. If the action succeeds, the anxiety and stress aspects of the situation are reduced and relieved, although the severity of the general fire situation may have increased.

## Reassessment

Reassessment and overcommitment are the most stressful of the individual's processes because previous attempts to adjust to the threat have failed. Thus, more intense effort goes into the behavioral reactions and the individual tends to become less selective in the choice of response. Encountering successive failures, the individual becomes more frustrated. The possibility of injury and risk increases with a greater activity level and with less probability of success, as was demonstrated in the Arundel Park fire. There, the number of those who selected windows as a means of escape increased as people became involved in their second escape attempts.[5]

In analyzing the behavior of an individual involved in the processes of recognition, validation, definition, evaluation, commitment, and reassessment, it must be remembered that these are dynamic processes. They are constantly being modified in relation to their magnitude, velocity, and intensity. A person's usual psychological and physiological activities will probably be below normal during the recognition process, when he or she is concentrating on perceiving the threat cues. During the process of validation and definition of the threat, adjacent members of the threatened population communicate overtly. The period of hyperactivity appears to occur initially during the process of commitment and to become intense during the process of reassessment and recommitment. Stress increases with each successive stage, as the primary motivation of the behavioral activity is stress reduction. Appearance, proximity, propagation, time, and toxic gases of the fire threat also tend to predispose the individual to a higher level of behavioral activity, again depending upon the individual's perception of these threat variables. During the process of reassessment and recommitment, the individual's activity level may assume the hyperactive mode of frantic activity, or it may be expressed in the catastrophic state of complete physical immobility with a loss of ability to communicate coherently. These individuals appear to perceive the threat as above their level of adaptability. The stress is too severe, and they give up completely. Thus, they cease to make any attempt at an adaptive behavior and retreat totally from the situation through the mechanism of psychological withdrawal. These behavioral dynamics are presented in Figure 4.1.2.

A conceptual model of the individual's decision processes similar to some concepts previously discussed has been developed. Instead of the six processes described, only three have been used: (1) recognition/interpretation; (2) behavior, with either action or inaction; and (3) the outcome of the action, which involves the evaluation and long-term effect of the behavior.[7] Behavior evaluation is similar to the process of reassessing the decision model. Both the recognition/interpretation concept and the behavior concept involve factors critical to the decision processes. Experience and immediate circumstances have an impact on the recognition/interpretation concept. It has been emphasized that individuals in a fire may not know right away that they are involved in a fire and may not know where, in relation to their location, the fire is developing or where the egress routes are. A concept of a heuristic (i.e., experimental or provisional) systems model is presented in Figure 4.1.3.

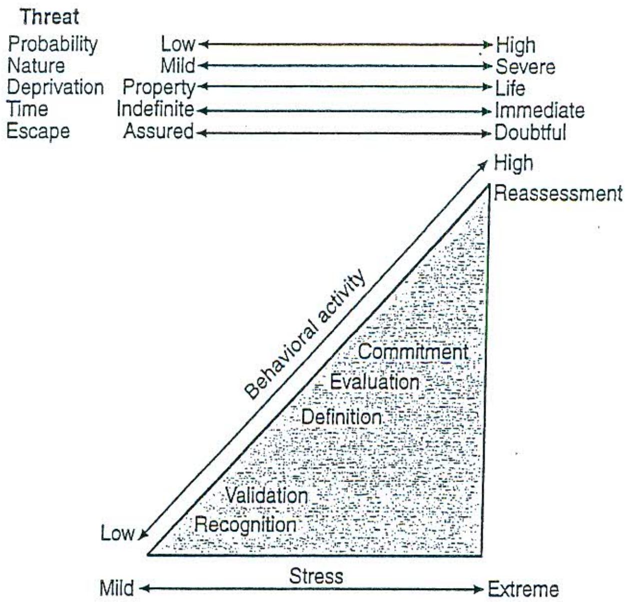


**FIGURE 4.1.2** *Dynamics of Behavioral Activity of the Individual*

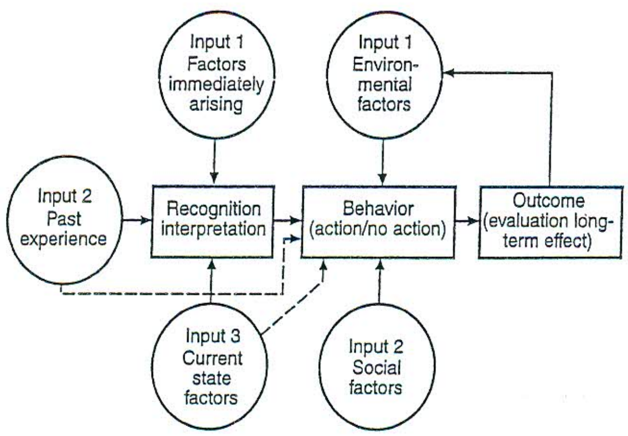


**FIGURE 4.1.3** *Preliminary Heuristic Systems Model of Behavior in Fires*

The conceptual model just described has been modified into one involving three phases: (1) detection of cues, (2) definition of the situation, and (3) coping behavior. In addition, tentative determinants of the behavior have been developed, which increase the probability of detection and of fire suppression.[37]

Proulx[38] developed a stress model to demonstrate various levels of stress generation within an individual involved in the decision process during a fire incident. Figure 4.1.4 illustrates this stress model, which should be compared with the behavioral activity dynamics of the individual in a fire incident presented in Figure 4.1.2. The left side of Figure 4.1.4 indicates the information the individual must process; the right side indicates the emotional state that results. Proulx describes the five loops in the stress model as follows:

1. The first loop starts with the perception of ambiguous information. This information is decoded in the processing system (PS in the figure) for interpretation. Given that the available information may not allow for a straightforward assessment of the situation, people will at first minimize or deny the situation. These defensive strategies of avoidance lead to an absence of reaction.

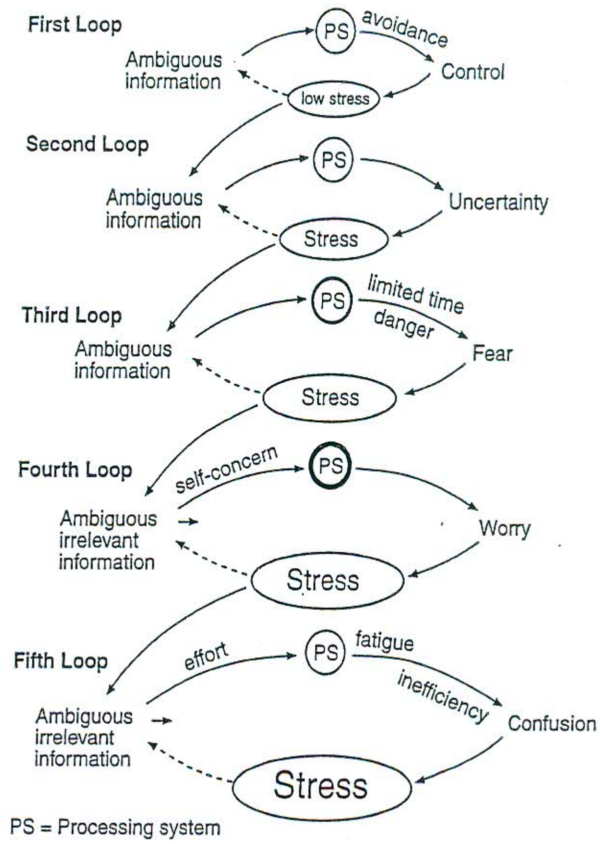


**FIGURE 4.1.4** *Stress Model of People in a Fire Situation*

2. Although individuals may vary considerably in their appraisal of the same event, the repeated perception of ambiguous information will eventually generate a state of uncertainty, which will then induce a feeling of stress. Some time can be spent going repeatedly through the second loop.
3. The third loop is related to the interpretation of the situation as an emergency. The thicker line around the processing system expresses the pressure of the overload of information with which the person tries to deal at once. The fear felt by the person is a manifestation of a specific appraisal of the environment.
4. The fourth loop relates to the person's processing of irrelevant information and is represented by the very thick line around the processing system. This irrelevant information creates worry and more stress. The irrelevant information, created by the person, is caused by concern for his or her own performance in coping with the situation. Perceived feelings of arousal and fear, uncertainties regarding how to proceed with the problem, difficulties in interpreting what exactly is going on, and self-estimation of the efficiency of already applied actions become additional information to process.
5. The fifth loop supposes an investment of more mental effort to master the problem, momentarily reducing the pressure

on the processing system, but resulting in fatigue and inefficiency manifested in a state of confusion.

Proulx indicates that definitive, valid, and directive information provided to occupants of a building in a fire incident most effectively reduces stress and thus tends to minimize response delays created in the first and second loops of the stress model.

Chubb[39] proposes that the model of the decision processes that fire department officers use in the incident command procedure be adopted as the decision process of building occupants in a fire situation. The decision model was developed from the theory of naturalistic decision making, which evolved from studies of decision makers in complex, time-critical situations. The critical variables of naturalistic decision-making theory appear to share many environmental and psychological features of fire situations involving building occupants. Chubb identified these critical variables:

- Ill-defined goals and ill-structured tasks
- Uncertainty, ambiguity, and missing data
- Shifting and competing goals
- Dynamic and continually changing conditions
- Real-time reactions to changed conditions
- Time stress
- High stakes
- Organizational goals and norms
- Experienced decision makers

Figure 4.1.5 illustrates the Recognition-Primed Decision (RPD) model developed by Klein[40] from studies of fire department officers. Chubb correctly indicated this model's limitation when applied to building occupants: They lack the dynamic abilities—suitable training and previous experience—in building fires that fire officers have. Static abilities relative to building occupants' mental and physical capabilities also appear to be more varied and limited than those of fire officers'. Chubb indicates that successful recognition-primed decision making depends on occupant training and practice of fire safety plans, with the decision support system in the building consisting of egress signs, emergency lighting, and vocal communication systems.

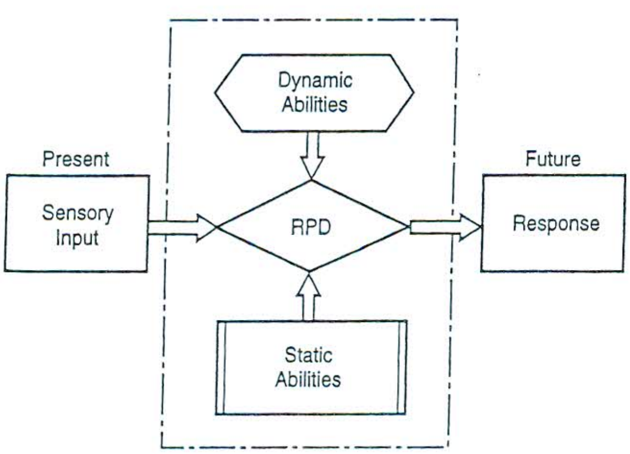


FIGURE 4.1.5 *Recognition-Primed Decision Model*

## BEHAVIOR ACTIONS OF OCCUPANTS

A study involving 952 fires and 2193 individuals interviewed by fire department personnel at the scenes of fires in England found that the most frequent responses to fire involved evacuating the building, fighting or containing the fire, and alerting other individuals or the fire brigade.[15] An identical broad behavior categorization was found in a similar study, which involved interviewing 584 participants in 335 fire incidents in the United States. Interviews were conducted by fire department personnel, who used a structured questionnaire at the scene of the fires.[8]

Examination of initial actions to fire is presented in Table 4.1.3. Behavior of the individuals also varied by sex: males were predominately active in fighting the fire, whereas females predominately concerned with alerting and helping others leave the building.

### Comparison of the First Actions of British and U.S. Study Populations

It should be noted that there were 10 statistically significant differences between the British and U.S. study populations. The U.S. study population was more likely to report five categories of first actions: "notified others," "got dressed," "got family," "left area," and "entered the building." A higher percentage of the British population reported as first actions "fought fire," "went to fire area," "closed door to fire area," "pulled fire alarm," and "turned off appliances."

### Comparison of the Behavior of the British and U.S. Study Populations

The general classification of the three early actions for the British and the U.S. study populations alike were categorized as "evacuation," "reentry," "fire fighting," "moved through smoke," and "turned back" behavior. Comparison of the two populations is presented in Table 4.1.4. There was a statistically significant difference between British and U.S. populations in every category except "moved through smoke."

### Summary of the First, Second, and Third Actions of the Occupants

An interesting aspect of the U.S. study involves variation in the first, second, and third actions reported by participants. Table 4.1.5 presents the three actions for the group, totaling 584 individuals. "Notifying others" accounted for 15 percent of the first actions, but by the time of the third actions, it accounted for only 5.8 percent. A similar reduction in frequency can be observed for "searching for the fire." This activity decreases from 10.1 percent as the first action to 0.8 percent as the third action. The actions "got dressed" and "got family" also reduced in frequency with the progression from the first to the third action as time passed during the fire. In contrast, "left building," "fought fire," and "called fire department," increased in frequency from the first to the third actions.

Canter, Breaux and Sime[41] developed a decomposition diagram of the acts of 41 persons in 14 domestic fires. This study,

**TABLE 4.1.3** *Comparison of the First Actions of a British and U.S. Study Population*

| Action | British (percent, $P_1$) | U.S. (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1 - P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| Notified others | 8.1 | 15.0 | 6.9 | 1.38 | 5.00 |
| Searched for fire | 12.2 | 10.1 | 2.1 | 1.51 | 1.39 |
| Called fire department | 10.1 | 9.0 | 1.1 | 1.40 | 0.79 |
| Got dressed | 2.2 | 8.1 | 5.9 | 0.85 | $6.94^c$ |
| Left building | 8.0 | 7.6 | 0.4 | 1.27 | 0.31 |
| Got family | 5.4 | 7.6 | 2.2 | 1.11 | $1.98^c$ |
| Fought fire | 14.9 | 10.4 | 4.5 | 1.63 | $2.76^c$ |
| Left area | 1.8 | 4.3 | 2.5 | 0.70 | $3.57^c$ |
| Nothing | 2.1 | 2.7 | 0.6 | 0.69 | 0.87 |
| Had others call fire department | 2.8 | 2.2 | 0.6 | 0.76 | 0.79 |
| Got personal property | 1.2 | 2.1 | 0.9 | 0.55 | 1.64 |
| Went to fire area | 5.6 | 2.1 | 3.5 | 1.01 | $3.47^c$ |
| Removed fuel | 1.2 | 1.7 | 0.5 | 0.53 | 0.94 |
| Entered building | 0.1 | 1.6 | 1.5 | 0.30 | $5.00^c$ |
| Tried to exit | 1.6 | 1.6 | 0.0 | 0.00 | 0.00 |
| Closed door to fire area | 3.1 | 1.0 | 2.1 | 0.76 | $2.76^c$ |
| Pulled fire alarm | 2.7 | 0.9 | 1.8 | 0.70 | $2.57^d$ |
| Turned off appliances | 4.1 | 0.9 | 3.2 | 0.85 | $3.20^c$ |
| $N = 18$ | 2193 | 580 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.
[d]Critical ratios significant at or above the 5 percent level of confidence.

conducted in the United Kingdom, covers home fires, as do the studies by Wood[15] and Bryan[8] discussed previously. Figure 4.1.6 presents this decomposition diagram and should be compared with Tables 4.1.3 through 4.1.5. The sequence of the first, second, and third actions of the U.S. study population are generally similar to the sequence of actions in the decomposition diagram.

## Summary of the First Actions of the Occupants, According to Sex

Differences between the first actions of the participants according to their sex have been examined. Table 4.1.6 presents the reported initial actions of the U.S. study population relative to the sex of the participants.

Statistical differences between males and females are significant in the categories "searched for fire," "called fire department," "got family," and "got extinguishers." Male participants more frequently reported investigation and fire-fighting activities. For example, 14.9 percent of the males "searched for fire," as opposed to 6.3 percent of the females; 6.9 percent of the males "got extinguishers," as opposed to 2.8 percent of the females. Females more frequently reported warning and evacuation activities. For example, 11.4 percent of the females "called fire department" as their initial action, as opposed to 6.1 percent of the male participants. In relation to evacuation behavior, 10.4 percent of the females reported "left building" as the first action, contrasted with 4.2 percent of the male participants. The influence of cultural roles is probably indicated explicitly in the concern for other family members—11 percent of the females "got family" as the first action, whereas only 3.4 percent of males engaged in this as an initial action. It should be noted that the second and third prevalent male actions of "searched for fire" and "got extinguishers" were equated to the female actions of "called fire department" and "got family."[8] This behavior has also been observed in healthcare and educational fires.

## Behavior in Hotel Fires

Fire protection of high-rise buildings and their occupants was tested severely by the MGM Grand Hotel fire in Clark County, Nevada, on November 21, 1980,[42] and by the subsequent fire at the Las Vegas Hilton Hotel on February 10, 1981.[43] Both these hotel fires resulted in injuries and fatalities among guests. NFPA conducted an intensive questionnaire study of the guests registered in the MGM Grand Hotel on the evening of November 20–21, 1980.[44]

The MGM Grand Hotel fire was discovered by a hotel employee who entered the unoccupied deli-restaurant located on the casino level of the hotel at approximately 7:10 a.m. on November 21, 1980. As instructed, the hotel telephone operator immediately notified the Clark County Fire Department at approximately 7:18 a.m. The telephone operators were forced from their switchboard by the smoke immediately after they had made an announcement over the public address system, at approximately 7:20 a.m., to evacuate the casino area. The fire

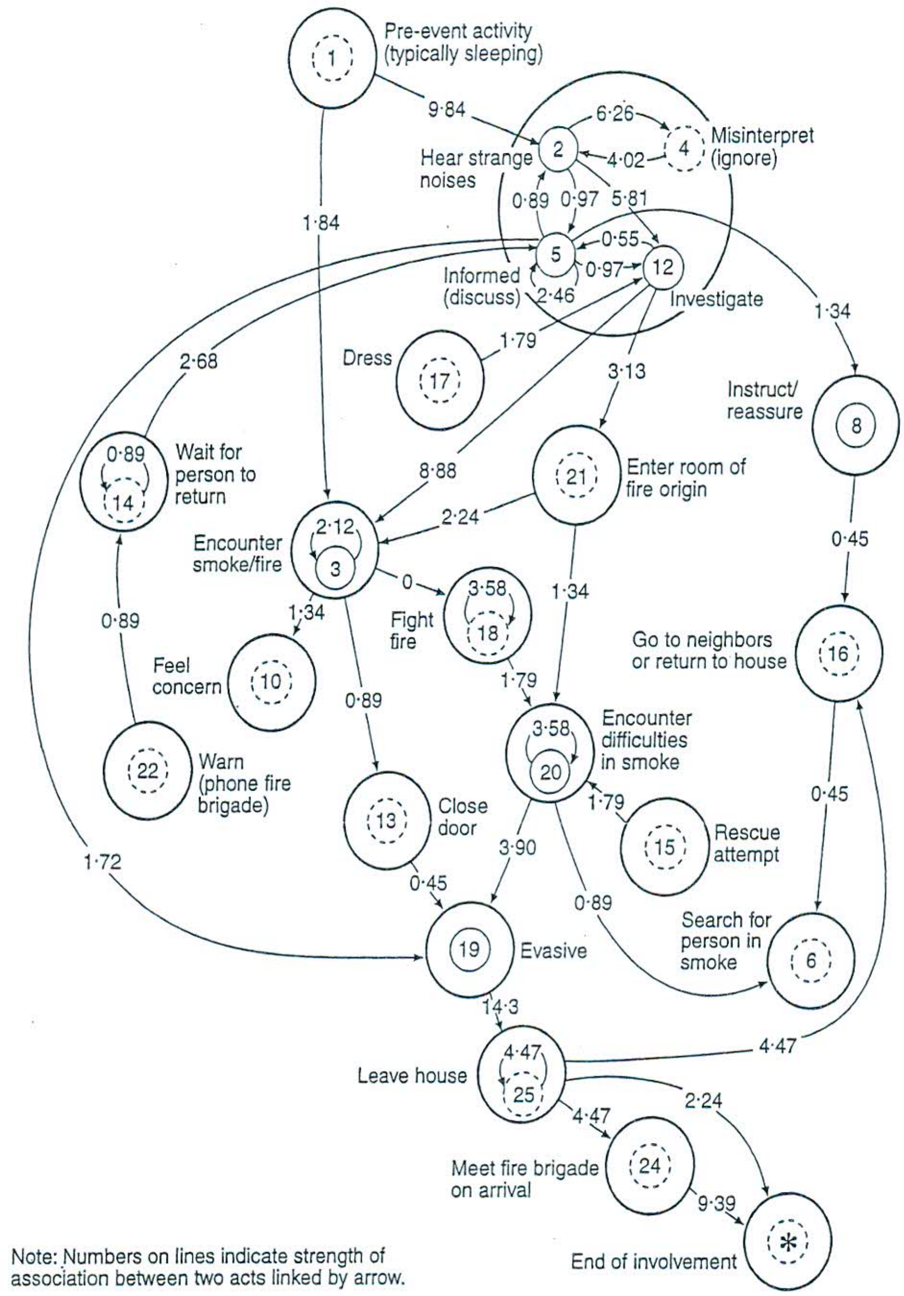


**FIGURE 4.1.6** *Decomposition Diagram—Domestic Fires*

**TABLE 4.1.4** *Comparison of the Behavior of the British and U.S. Study Populations*

| Behavior | British (percent, $P_1$) | U.S. (percent, $P_2$) | $P_1 - P_2$ | $SE^{a}_{P_1-P_2}$ | $CR^{b}$ |
|---|---|---|---|---|---|
| Evacuation | 54.5 | 80.0 | 25.5 | 2.30 | 11.09[c] |
| Reentry | 43.0 | 27.9 | 15.1 | 2.30 | 6.51[c] |
| Fire fighting | 14.7 | 22.9 | 8.2 | 1.74 | 4.71[c] |
| Moved through smoke | 60.0 | 62.7 | 2.7 | 2.29 | 1.18 |
| Turned back | 26.0 | 18.3 | 7.7 | 2.01 | 3.83[c] |
| | 2193 | 584 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.

TABLE 4.1.5 *Summary of the First, Second, and Third Actions of the Occupants*

| | Action (percent) | | |
|---|---|---|---|
| | First | Second | Third |
| Notified others | 15.0 | 9.6 | 5.8 |
| Searched for fire | 10.1 | 2.4 | 0.8 |
| Called fire department | 9.0 | 14.6 | 12.7 |
| Got dressed | 8.1 | 1.8 | 0.3 |
| Left building | 7.6 | 20.9 | 35.9 |
| Got family | 7.6 | 5.9 | 1.4 |
| Fought fire | 4.6 | 5.7 | 11.5 |
| Got extinguisher | 4.6 | 5.3 | 1.6 |
| Left area | 4.3 | 2.8 | 1.1 |
| Woke up | 3.1 | 0.0 | 0.0 |
| Nothing | 2.7 | 0.0 | 0.0 |
| Had others call fire department | 2.2 | 4.0 | 4.1 |
| Got personal property | 2.1 | 3.8 | 0.8 |
| Went to fire area | 2.1 | 1.0 | 0.0 |
| Removed fuel | 1.7 | 1.0 | 1.1 |
| Entered building | 1.6 | 0.8 | 1.1 |
| Tried to exit | 1.6 | 2.4 | 0.5 |
| Went to fire alarm | 1.6 | 1.8 | 1.1 |
| Telephoned others | 1.2 | 0.6 | 1.1 |
| Tried to extinguish | 1.2 | 1.8 | 1.9 |
| Closed door to fire area | 1.0 | 0.2 | 0.3 |
| Pulled fire alarm | 0.9 | 0.6 | 0.5 |
| Turned off appliances | 0.9 | 0.6 | 0.3 |
| Checked on pets | 0.9 | 1.4 | 0.5 |
| Awaited fire department arrival | 0.0 | 1.0 | 3.6 |
| Went to balcony | 0.2 | 0.8 | 2.7 |
| Removed by fire department | 0.0 | 0.0 | 1.6 |
| Opened doors/windows | 0.2 | 0.4 | 1.1 |
| Other | 3.9 | 8.0 | 6.6 |
| *N* = 29 | 100.0 | 100.0 | 100.0 |
| Range | 0–87 | 0–106 | 0–131 |
| Percent of participant population | 99.3 | 86.6 | 62.9 |

quickly reached flashover in the deli, immediately spread from east to west through the main casino area, and extended out the west portico doors on the casino level immediately following the arrival of the first fire department personnel.

An addition to the hotel was being constructed adjacent to the west end of the building, and construction workers helped warn and evacuate guests and assisted in fire fighting. The heat and smoke rapidly extended from the casino area through the seismic joints, elevator shafts, and stairways throughout the 21 residential floors of the hotel. The heat was intense enough on the 26th floor, a top floor, to activate automatic sprinklers in the lobby adjacent to the elevator shafts.

Due to the rapid early evacuation of the telephone sta guests were not alerted by the hotel public address system or t local fire alarm system. Guests warned early in the fire, a those already awake and dressed, were able to escape before t smoke became untenable on the upper floors. Guests alert later remained in their rooms or moved to other rooms, usual with other occupants. The fire itself did not extend above t casino level, except in a rather minor nature, into two gue rooms on the fifth floor. The fire resulted in 85 fatalities and i jured 778 guests and 7 hotel employees. Seventy-nine body l cations were documented: 18 on the casino level, 25 in gue rooms, 22 in corridors and lobbies, 9 in stairways, and 5 in el vators. The victims were found on the casino level and on th 16th and floors above, with the majority between the 20th an the 25th floors.

Figure 4.1.7 is a diagram of the guest floor of the MGM Grand Hotel that was used in the engineering study conducted b NFPA.[42] Of the 9 victims found in the stairways, 2 were in stair way 1 at the extreme south end of the south wing on the 17th floor; 6 were between the 20th and 23rd floor in stairway 2 at the central end of the south wing; and 1 was found at the ground-floor level of stairway 4 at the extreme west end of the west wing There are various estimates of the number of guests and fire department personnel who suffered injuries at the MGM Grand Hotel fire. Morris indicated that 619 people were taken to hospitals, and another 150 were treated at the Las Vegas Convention Center, where the survivors were transported from the hotel.[45]

The MGM Grand Hotel tragedy was a unique fire, especially from two aspects: (1) it was the second most serious hotel fire in U.S. history, surpassed only by the Winecoff Hotel fire in Atlanta, Georgia, on December 7, 1946, which killed 119; and (2) it was the first high-rise fire in the United States in which helicopters evacuated large numbers of people. About 300 were evacuated in this manner; the fire department rescued approximately 900 people by other means.

Shortly after the MGM Grand Hotel fire, NFPA prepared a four-page, 28-item questionnaire that included the floor plan of the guest rooms. A total of 1960 questionnaires were mailed, and 554, or approximately 28 percent, of these were returned. Of the respondents, 455 indicated a willingness to be interviewed.

The age of the questionnaire population ranged from 20 to 84 years, with an average age of 45. The population consisted of 331 males and 222 females; one respondent did not indicate a sexual classification. One-hundred and three guests indicated that they were alone at the time they became aware of the fire in the hotel. The presence of other people, especially if they belong to the individual's primary group, appears to be a determinant of the response of many individuals in residential fires.[8]

The initial five actions reported by the 554 guests, as elicited from the NFPA questionnaire study, are presented in Table 4.1.7. Notice that the five most frequent first actions were "dressed," "opened door," "notified roommates," "dressed partially," and "looked out window." Guests reporting these actions were predominately engaged in determining the degree of threat to themselves. Only 7.9 percent of the study population began or tried to begin their own evacuation with such actions as "attempted to exit," "went to exit," and "left room." A total of 16 in-

**TABLE 4.1.6** *First Actions of the Occupants, According to Sex of Occupant*

| First Action | Male (percent, $P_1$) | Female (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1-P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| Notified others | 16.3 | 13.8 | 2.5 | 2.98 | 0.83 |
| Searched for fire | 14.9 | 6.3 | 8.6 | 2.51 | 3.43[c] |
| Called fire department | 6.1 | 11.4 | 5.3 | 2.41 | 2.19[d] |
| Got dressed | 5.8 | 10.1 | 4.3 | 2.30 | 1.87 |
| Left building | 4.2 | 10.4 | 6.2 | 2.22 | 2.79[c] |
| Got family | 3.4 | 11.0 | 7.6 | 2.22 | 3.42[c] |
| Fought fire | 5.8 | 3.8 | 2.0 | 1.77 | 1.13 |
| Got extinguisher | 6.9 | 2.8 | 4.1 | 1.77 | 2.31[d] |
| Left area | 4.6 | 4.1 | 0.5 | 1.70 | 0.29 |
| Woke up | 3.8 | 2.5 | 1.3 | 1.45 | 0.90 |
| Nothing | 2.7 | 2.8 | 0.1 | 1.38 | 0.72 |
| Had others call fire department | 3.4 | 1.3 | 2.1 | 1.23 | 1.71 |
| Got personal property | 1.5 | 2.5 | 1.0 | 1.17 | 0.85 |
| Went to fire area | 1.9 | 2.2 | 0.3 | 1.20 | 0.25 |
| Removed fuel | 1.1 | 2.2 | 1.1 | 1.08 | 1.02 |
| Entered building | 2.3 | 0.09 | 1.4 | 1.02 | 1.37 |
| Tried to exit | 1.5 | 1.6 | 0.1 | 1.05 | 0.09 |
| Went to fire alarm | 1.1 | 0.19 | 0.8 | 1.02 | 0.78 |
| Telephoned others | 0.8 | 1.6 | 0.8 | 0.91 | 0.87 |
| Tried to extinguish | 1.9 | 0.6 | 1.3 | 0.91 | 1.43 |
| Closed door to fire area | 0.8 | 1.3 | 0.5 | 0.87 | 0.57 |
| Pulled fire alarm | 1.1 | 0.6 | 0.5 | 0.75 | 0.66 |
| Turned off appliances | 0.8 | 0.9 | 0.1 | 0.79 | 0.12 |
| Checked on pets | 0.8 | 0.9 | 0.1 | 0.79 | 0.12 |
| Other | 6.5 | 2.5 | 4.0 | 1.70 | 2.35[d] |
| $N = 25$ | 262 | 318 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.
[d]Critical ratios significant at or above the 5 percent level of confidence.

dividuals, or 2.9 percent of the population, initiated actions to improve the room as an area of refuge: "wet towels for face" and "put towels around door." The actions of the guests could be classified, in general, as evacuation actions or refuge processes. Actions relating to evacuation behavior appeared to be initiated early if the egress passages were clear of smoke or if the smoke was not perceived as personally threatening. If the smoke was heavy, however, the guests apparently decided to stay in their rooms or other rooms and to initiate actions to prevent smoke migration into the rooms of refuge.

Further examination of Table 4.1.7 shows that the five actions most frequently reported by guests as their second actions were "opened door," "dressed," "went to exit," "dressed partially," and "secured valuables." Approximately 19 percent of the study population reported dressing before initiating evacuation or refuge procedures.

The third actions of guests in the study population generally progressed to evacuation, attempted evacuation, and notification. Approximately 25 percent of this population was involved in evacuation actions, and approximately 10 percent attempted evacuations, as identified by the third actions of "attempted to exit" and "returned to room." The alerting and notification actions are identified as "notified occupants" and "notified other room."

The fourth actions of the guests in the study population indicate a progression to evacuation, attempted evacuation, and self-protection or room refuge actions. The most frequently reported fourth action was "went to exit"; approximately 16 percent of the population indicated that they did this. However, when one combines the guests involved in this action with those who "went down stairs," "went to another exit," "left hotel," and "left room," a total of 151 guests, or approximately 30 percent of the fourth action guest population, were involved in evacuation actions. The process of forming convergence clusters was noted in this hotel fire. This action involved individuals clustering together in rooms they considered areas of refuge with individuals they usually characterized as strangers before the fire. The fourth actions of "went to other room" and "went to other room/others" are explicit indicators of the formation of convergence clusters.[46]

The fifth actions of the guests were primarily for self-protection and included improving the room as an area of refuge

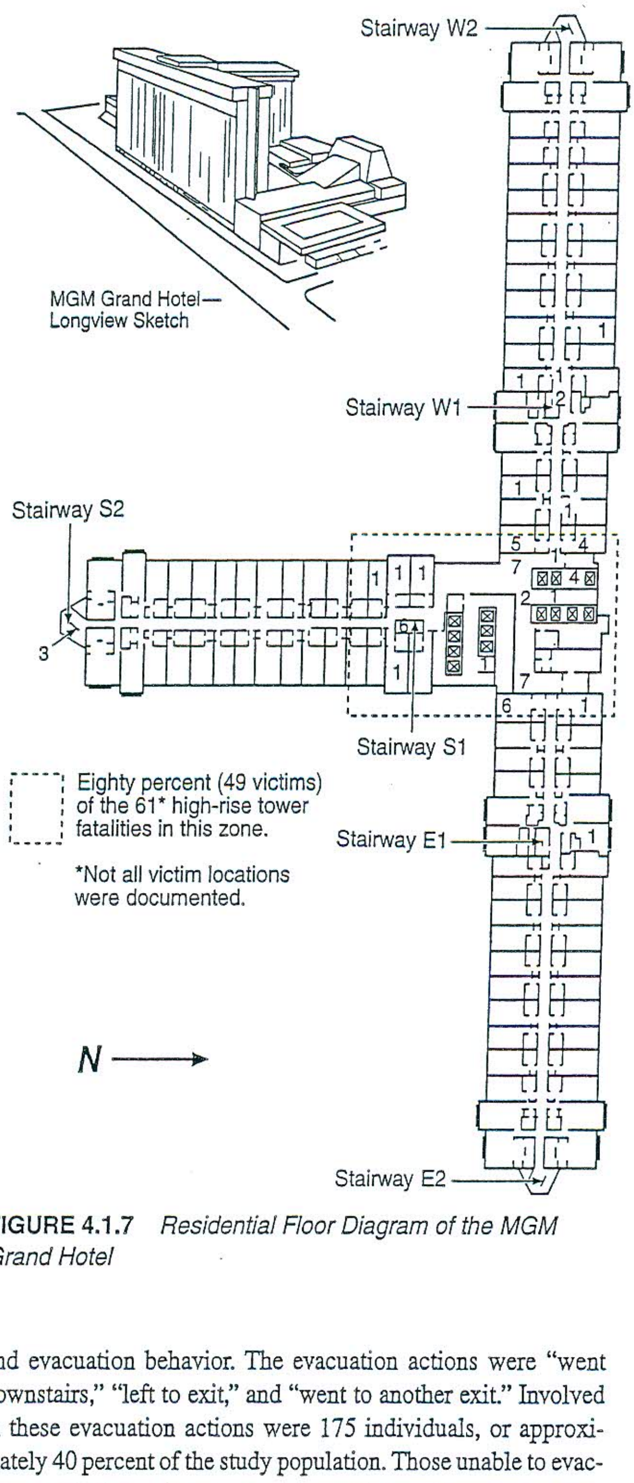


**FIGURE 4.1.7** *Residential Floor Diagram of the MGM Grand Hotel*

and evacuation behavior. The evacuation actions were "went downstairs," "left to exit," and "went to another exit." Involved in these evacuation actions were 175 individuals, or approximately 40 percent of the study population. Those unable to evacuate, and thus vitally concerned with refuge procedures, reported the fifth actions of "went to other room/others," "wet towels for face," "put towels around door," "broke window," "returned to room," "went to other room," "offered refuge in room," and "went to balcony." Approximately 40 percent of the fifth-action study population was involved in refuge procedures and self-protection actions.

## Convergence Clusters

The phenomenon of convergence cluster formation was first noticed in a study of occupant behavior in a high-rise apartment building fire in 1979.[47] The clusters appear to involve occupants of the building who converged into specific rooms they perceived as areas of refuge. In the MGM Grand Hotel fire, guest tended to select rooms on the north side of the east and wes wings and rooms on the east side of the south wing. In addition guests reported that people had converged in the rooms with balconies and doors leading out to the balconies because of the ventilation, reduced smoke, improved visibility, and communication that the balconies offered. Guests who reported this behavior either estimated the number of persons in the room or connecting rooms, or they indicated only that "others" or "other persons" were present.

Table 4.1.8 lists the rooms identified by guests as areas of refuge for numerous persons other than the original occupants. This table also presents estimates of the length of time that the clusters were maintained in the rooms—usually until the individuals were evacuated, or until the occupants were notified by fire or rescue personnel that evacuation was possible. Numbers in the two right-hand columns indicate the total number of persons in the clusters for the total number of rooms identified on the floor. The smallest number of people identified as a cluster was 3, and the largest was 35.

The greatest number of rooms used by convergence clusters and the largest population participating in convergence clusters were located on the 17th floor of the hotel. No convergence clusters were identified by guests on the 6th, 21st, or 26th floors. The clusters appear to serve as an anxiety- and tension-reducing mechanisms for individuals confronted with a threatening situation. The action of "offered refuge in room," previously identified in the discussion of the fifth actions, is a positive indication of the occurrence of a convergence cluster.

In addition to the detailed human behavior study of the MGM Grand Hotel fire,[48] NFPA conducted a questionnaire study of guests' behavior in the Westchase Hilton Hotel fire in Houston, Texas, on March 6, 1982, in which 12 people died.[49]

Figure 4.1.8 presents the decomposition diagram for eight multiple occupancy fires covering the actions of 96 persons.[41] These multiple occupancy fires in the United Kingdom involved hotel occupancies. A comparison of Figure 4.1.8 with Table 4.1.7 shows similarities between the five actions of the guests in the MGM Grand Hotel fire and the occupants' behavior in the British study.

The classic types of nonadaptive behavior in a fire ignore adaptive actions that might facilitate the evacuation of others or limit the propagation of smoke, heat, or flame. Nonadaptive behavior ranges from the single act of leaving a room of fire origin without closing the door, thus allowing the fire to spread throughout the structure and endanger the lives of all the occupants, to the more generalized behavior of fleeing from a fire without regard for others and perhaps injuring others in what is often termed "panic."

Nonadaptive behavior may be an omission, such as forgetting to close a door, or it may involve an action that, although well meaning, results in negative consequences. When the results of behavior are extinguishing the fire and eliminating the threat, the behavior may be said to be adaptive. However, the same behavior may be ineffective because the fire was more severe than was first perceived. In such cases, the time spent try-

TABLE 4.1.7 *First Five Reported Actions of Guests in the MGM Grand Hotel Fire*

| | Action (percent of population) | | | | |
|---|---|---|---|---|---|
| | First | Second | Third | Fourth | Fifth |
| Dressed | 16.8 | 11.6 | 6.5 | — | — |
| Opened door | 15.9 | 11.7 | 6.7 | 3.4 | — |
| Notified roommates | 11.6 | 3.0 | — | — | — |
| Dressed partially | 10.1 | 7.5 | 4.5 | — | — |
| Looked out of window | 9.7 | 5.7 | — | — | — |
| Got out of bed | 4.5 | — | — | — | — |
| Left room | 4.3 | 5.4 | 8.1 | 2.4 | 2.0 |
| Attempted to phone | 3.4 | 3.6 | — | 2.8 | — |
| Went to exit | 2.5 | 10.3 | 9.5 | 16.1 | 6.7 |
| Put towels around door | 1.6 | 2.5 | 3.0 | 6.8 | 7.7 |
| Felt door for heat | 1.3 | 2.3 | — | — | — |
| Wet towels for face | 1.3 | 3.7 | 6.3 | 4.6 | 7.9 |
| Got out of bath | 1.1 | — | — | — | — |
| Attempted to exit | 1.1 | 3.0 | 5.8 | 4.3 | — |
| Secured valuables | — | 6.8 | 4.3 | — | — |
| Notified other rooms | — | 3.4 | 2.2 | — | — |
| Returned to room | — | — | 3.9 | 8.4 | 4.1 |
| Went down stairs | — | — | 3.9 | 5.4 | 21.3 |
| Left hotel | — | — | 3.4 | 2.6 | 2.0 |
| Notified occupants | — | — | 3.0 | — | — |
| Went to another exit | — | — | — | 3.6 | 4.8 |
| Went to other room | — | — | — | 3.6 | 3.6 |
| Went to other room/others | — | — | — | 3.4 | 8.7 |
| Looked for exit | — | — | — | 2.4 | — |
| Broke window | — | — | — | — | 4.3 |
| Offered refuge in room | — | — | — | — | 1.8 |
| Went upstairs to roof | — | — | — | — | 2.9 |
| Went to balcony | — | — | — | — | 1.8 |
| Other | 14.8 | 19.5 | 28.9 | 30.2 | 20.1 |
| Total (percent) | 100.0 | 99.1 | 96.9 | 90.6 | 79.6 |
| No. of guests | 554 | 549 | 537 | 502 | 441 |

ing to extinguish it might have been used more effectively to warn others and to notify the fire department. Thus, some behavior that appears to be nonadaptive really is behavior that would have seemed most adaptive if it had been successful. Injuries people suffer in relation to a fire may be cues to their nonadaptive or risk behavior.

## Panic Behavior

One concept always discussed following a fire in which multiple fatalities occur, such as the Beverly Hills Supper Club fire,[50] is panic behavior. One classic definition of panic is

> A sudden and excessive feeling of alarm or fear, usually affecting a body of persons, originating in some real or supposed danger, vaguely apprehended, and leading to extravagant and injudicious efforts to secure safety.[51]

According to this definition, panic is a flight or fleeing type of behavior that involves extravagant and injudicious effort and is likely not to be limited to a single individual, but to be transmitted to and adopted by a group of people. From simulation experiments, a panic-type behavior reaction has been defined in the following manner: "A fear-induced flight behavior which is nonrational, nonadaptive, and nonsocial, which serves to reduce the escape possibilities of the group as a whole."[52]

The concept of panic is often used to explain the occurrence of multiple fatalities in fires even when there is no physical, social, or psychological evidence showing that competitive, injudicious flight behavior actually took place. The media and public officials often label various types of fire behavior as panic. The evidence accumulated from interviews with participants in the Beverly Hills Supper Club fire, and questionnaires completed by occupants, provided no evidence of the classic group-type of panic behavior with competitive flight for the exits.[53]

It has been said that panic as a concept is primarily a description rather than an explanation of behavior. The concept is used to support the introduction of requirements in fire and building laws or ordinances to provide for the fire safety of

TABLE 4.1.8 *Summary of Rooms, Time Duration, and Number of Guests Reported in Convergence Clusters*

| | Floor | Room Number(s) | Time (hr) | Persons Number | Persons Percent |
|---|---|---|---|---|---|
| | 7 | 731 | 0.6 | 3 | 0.7 |
| | 8 | 827, 840 | 1.5–1.75 | 14[a] | 3.3 |
| | 9 | 927 | 2.5 | 5 | 1.2 |
| | 10 | 1009A, 1025, 1034, 1060 | 1–2 | 53 | 12.7 |
| | 11 | 1129, 1115 | 1.5–2 | 30[a] | 7.2 |
| | 12 | 1261, 1225, 1233A | 2–3 | 53 | 12.7 |
| | 14 | 1433A, 1461A, 1451, 1416A | 1.5–2 | 8[a] | 1.9 |
| | 15 | 1501, 1533A, 1510 | 2–3 | 38[a] | 9.1 |
| | 16 | 1643, 1625, 1633, 1629, 1627, 1615 | 2–3.5 | 35[a] | 8.4 |
| | 17 | 1725, 1775, 1731, 1719, 1762, 1756, 1733A | 2–2.5 | 84 | 20.1 |
| | 18 | 1819, 1802, 1850 | 2–3 | 20 | 4.8 |
| | 19 | 1929, 1919, 1962A, 1962, 1964, 1925 | 2–3.5 | 13[a] | 3.1 |
| | 20 | 2027, 2013, 2030 | 2.5–3.5 | 25 | 6.0 |
| | 22 | 2213, 2221, 2229 | 2–3 | 13 | 3.1 |
| | 23 | 2329, 2314, 2342, 2331, 2308, 2340 | 2.5–3.25 | 20[a] | 4.8 |
| | 24 | 2446 | 3.5 | 4 | 0.9 |
| | 25 | 2512, 2509A | 3.5 | [a] | 0 |
| Total | 17 | 57 | | 418 | 100.0 |
| Range | 7–25 | 1–7 | 0.6–3.5 | 3–84 | 0–20.1 |

[a]Persons indicated only as "others."

occupants. There also has been shown to be a difference between use of the concept to describe other persons' behavior in a fire and the use by someone engaged in the behavior to indicate his or her own state of concern and anxiety.[54] Just because an individual identifies behavior as associated with panic does not necessarily identify the behavior as the classic panic-type response. The outcome of the behavior, as previously discussed, affects its labeling: the behavior of people in a fire is most likely to be misinterpreted when the outcome of the fire has been unfortunate.

The use of the concept of panic must be separated from use of the terms "anxiety" or "fear." The concept of self-destructive or animalistic panic responses to stimuli, such as the presence of smoke, has not been supported by the research on human behavior in fires. As has been pointed out, it is rare to have panic behavior in which the flight is characterized by competition among the participants, with resultant personal injuries.[8,15,16,54–56]

In an interview study of 100 participants in single-family dwelling fires, no instances of panic behavior were found; primarily altruistic, helpful behavior was found instead.[56]

Ramachandran[18] in his review of studies of human behavior in fires in the United Kingdom came to this conclusion about nonadaptive behavior:

> In the stress of a fire, people often act inappropriately and rarely panic or behave irrationally. Such behavior, to a large extent, is due to the fact that information initially available to people regarding the possible existence of a fire and its size and location is often ambiguous or inadequate.[18]

## Reentry Behavior

The study of the 1956 Arundel Park fire was the first to document the phenomenon of reentry behavior.[5] Some older codes and regulations affecting design of the means of egress appear to have been based on the assumption that pedestrian traffic only moves away from a fire and away from the area or floor of the building involved. However, the Arundel Park study indicated that approximately one-third of the survivors interviewed had reentered the building.

Thus, it has become apparent that doors, stairways, and corridors will be often subjected to two-way movement of occupants and others. The occupant who, after leaving the building safely, turns around and reenters is often completely aware of the fire in the building and of the specific portions of the building involved in fire and smoke propagation. Based on interviews with 61 persons, Table 4.1.9 presents the number of participants who reentered Arundel Park during the fire. Note the reasons for the reentry behavior and that those who reentered were predominately male.

The Arundel Park fire occurred in an assembly occupancy being used for a church-sponsored oyster roast, a family-type affair. Thus, the primary group cultural role of father or husband was apparently a critical variable in the reentry behavior of the population interviewed and may have resulted in the fact that the reentry participants were mostly male. It can reasonably be argued that reentry behavior is not a nonadaptive behavior, since it is often used to assist or rescue persons remaining or believed to be remaining in the building. This type of behavior is often used by parents whose children are missing during a fire. The

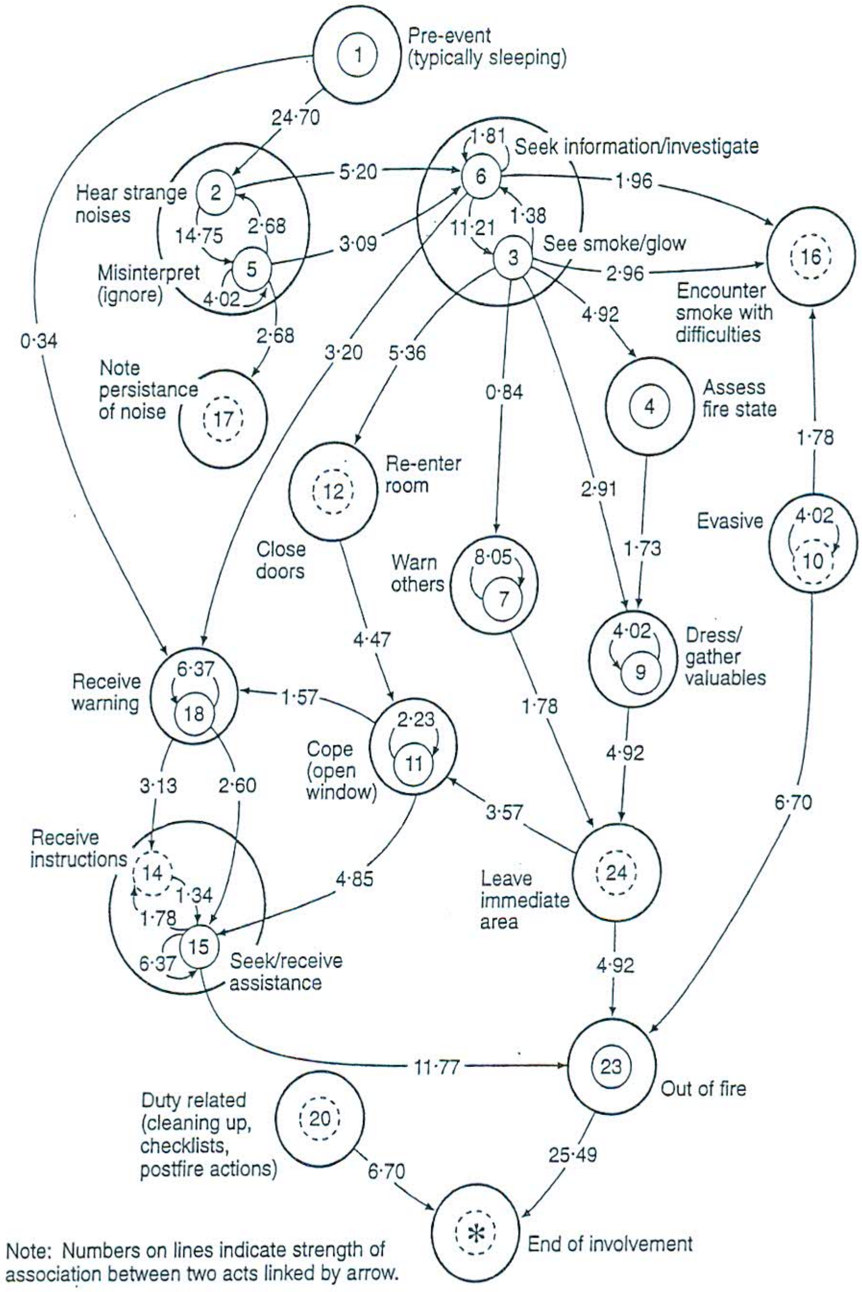


**FIGURE 4.1.8** *Decomposition Diagram for Multiple Occupancy Fires*

behavior is often undertaken in a rational, deliberate, and purposeful manner, without the emotional anxiety and self-doubt usually associated with nonadaptive behavior. However, reentry behavior has been considered nonadaptive, since people going back into a burning building often hinder the efficient and effective evacuation of others through the same means of egress.

The reasons elicited from participants in reentry behavior in the Project People study[8] in the United States are presented in Table 4.1.10. It would seem that 162 people from the total study population of 584, or 27.9 percent, engaged in reentry behavior. The most popular reason given was to "fight fire," followed by "obtain personal property," "check on fire," "notify others," "assist fire department," and "retrieve pets." These six reasons accounted for approximately 73 percent of this reentry behavior.

Table 4.1.11 compares the reentry behavior of the British and U.S. study populations. Note that all the reasons were significantly different, with the exception of the item "save personal effects." The reentry reasons of the U.S. population were predominantly "save personal effects," "call fire department," "rescue pets," "notify others," "assist fire department," and "assist evacuation." The British population's reentry reasons were predominantly "fight fire," "observe fire," "shut doors," "await fire department," and "fire not severe."

## Occupant Fire-Fighting Behavior

Occupants who engaged in fire fighting behavior were predominately male, and this behavior now appears to be a culturally

TABLE 4.1.9 *Behavior of Occupants Who Reentered in the Arundel Park Fire, Relative to Sex and Reentry Reasons*

| Sex | Reentered and Left by Same Exit | Reentered and Left by Different Exit | Stated Reason for Reentrance |
|---|---|---|---|
| M | 1 | | Turn off kitchen stoves |
| M | 1 | 1 | Tell people to leave |
| M | 3 | | To help |
| M | 1 | | Assist people |
| M | 2 | 3 | Find wife |
| M | 2 | 2 | Assist fire fighting |
| M & 1 F | | 5 | No stated reason |
| 21 M & 1 F | 10 | 12 | |

TABLE 4.1.10 *Reasons for Reentry of Occupants*

| Reason | Participants Number | Participants Percent |
|---|---|---|
| Fight fire | 36 | 22.2 |
| Obtain personal property | 28 | 17.2 |
| Check on fire | 18 | 11.0 |
| Notify others | 13 | 8.0 |
| Assist fire department | 12 | 7.4 |
| Retrieve pets | 12 | 7.4 |
| Call fire department | 9 | 5.5 |
| Assist evacuation | 4 | 2.5 |
| To be taken to hospital | 3 | 1.8 |
| Turn power back on | 2 | 1.2 |
| Rescue from balcony | 1 | 0.6 |
| Help injured family member | 1 | 0.6 |
| Turned off gas | 1 | 0.6 |
| Open windows | 1 | 0.6 |
| Close door | 1 | 0.6 |
| No apparent danger | 1 | 0.6 |
| Entered nondanger area | 1 | 0.6 |
| Job responsibility | 1 | 0.6 |
| Due to fire | 1 | 0.6 |
| Told to by others | 1 | 0.6 |
| Not reported | 16 | 9.8 |
| *N* = 21 | 163 | 100.0 |
| Range = 1–36 | Percent of participant population = 27.9 | |

determined and expected aspect of the male role. However, it should be noted that, in the Project People[8] study of 335 U.S. fires, approximately 23 percent of the study population of 584 individuals was involved in occupant fire fighting behavior. Of these, 37.3 percent were female. Of the 134 individuals who participated in fire fighting behavior, 50 were female and 84 male. They ranged from a 7-year-old girl to an 80-year-old man. Distribution of the participants by sex and age is presented in Table 4.1.12. Most of those involved in fire fighting behavior, or approximately 30 percent of the fire fighting behavior population, were between 28 and 37 years old.

A higher proportion of males than females reported "got extinguisher" and "fought fire," and this difference is statistically significant (Table 4.1.13). Approximately 15 percent of the male population reacted by obtaining extinguishers. Similarly, approximately 26 percent of the male population fought the fire when they became aware of it, as contrasted with approximately 10 percent of the female participants. A higher proportion of women notified the fire department: 33 percent of the females, compared with 26 percent of the males, reacted to the fire by notifying the fire department, as indicated in Table 4.1.13, but this difference is not statistically significant.

TABLE 4.1.11 *Comparison of Reasons for Reentry Behavior of British and U.S. Study Populations*

| Reason | British (percent, $P_1$) | U.S. (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1-P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| Fight fire | 36.0 | 22.2 | 13.8 | 4.02 | *3.43*[c] |
| Observe fire | 19.0 | 11.0 | 8.0 | 3.25 | *2.46*[d] |
| Save personal effects | 13.0 | 17.2 | 4.2 | 2.91 | 1.44 |
| Shut doors | 10.0 | 0.6 | 9.4 | 2.38 | *3.95*[c] |
| Await fire department | 9.0 | 0.0 | 9.0 | 2.26 | *3.98*[c] |
| Call fire department | 2.0 | 5.5 | 3.5 | 1.32 | *2.65*[c] |
| Rescue pets | 2.0 | 7.4 | 5.4 | 1.40 | *3.86*[c] |
| Fire not severe | 5.0 | 1.2 | 3.8 | 1.74 | *2.18*[d] |
| Notify others | 0.0 | 8.0 | 8.0 | 0.92 | *8.69*[c] |
| Assist fire department | 0.0 | 7.4 | 7.4 | 0.80 | *8.41*[c] |
| Assist evacuation | 0.0 | 2.5 | 2.5 | 0.54 | *4.63*[c] |
| *N* = 11 | 943 | 163 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.
[d]Critical ratios significant at or above the 5 percent level of confidence.

**TABLE 4.1.12** *Age and Sex of the Occupants Engaged in Fire-Fighting Behavior*

| | Participants | |
|---|---|---|
| | Number | Percent |
| Sex | | |
| Male | 84 | 62.7 |
| Female | 50 | 37.3 |
| Total | 134 | 100.0 |
| Age | | |
| 7–17 | 8 | 5.9 |
| 18–27 | 31 | 23.1 |
| 28–37 | 41 | 30.6 |
| 38–47 | 27 | 20.1 |
| 48–57 | 16 | 11.9 |
| 58–67 | 2 | 1.5 |
| 68–80 | 3 | 2.2 |
| Unknown | 6 | 4.7 |
| Total | 134 | 100.0 |
| | Percent of participant population = 22.9 | |

Occupant fire-fighting behavior appears most prevalent in occupancies in which the individuals are emotionally and economically involved—that is, in their homes or where such behavior is an assigned role as a result of training.[57] At some time during the fire, 285 individuals engaged in one of the six actions defined as fire-fighting behavior and 252 individuals participated in one of the four actions defined as notifying the fire department.

In the study of residential fire incidents in Berkeley, California, 180 persons were involved in extinguishing and fire-fighting behavior. This study surveyed a population different from that of Project People, since the 1411 Berkeley households, with 208 fires, included fires not reported to the fire department; these accounted for approximately 80 percent of the total 208 fires. The majority of the unreported fires were extinguished by the occupants alone or with the help of neighbors.[58] Six percent of these fires self-extinguished, and 52 percent were extinguished by the individual who had started the fire. Thus, it appears that only the fires in the Project People study that were judged uncontrollable by the occupants resulted in notification to the fire department. Similarly, approximately 85 percent of the fires in the National Fire Prevention and Control Administration National Household Survey[59] were not reported to the fire department.

In the Project People study, 107 of the 584 participants did not leave the building voluntarily after becoming aware of the fire. Their reasons for staying in the building are presented in Table 4.1.14. Fifty-two of the participants, or approximately 49 percent of the population, who stayed in the building reported that they remained because they wished to engage in fire control or fire-fighting activities. The other most frequent reasons were to notify others of the fire or because the occupant's way out of the building was blocked by smoke.

## Occupants' Movement Through Smoke

Often related to fire-fighting behavior, and a definite component of evacuation behavior in many fires,[8,15] is the movement of

**TABLE 4.1.13** *Sexual Differences of the Occupants Engaging in Fire Fighting and Notifying the Fire Department*

| Action | Male (percent, $P_1$) | Female (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1 - P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| Searched for fire | 17.2 | 9.1 | 8.1 | 4.23 | 1.91 |
| Got extinguisher | 15.6 | 6.0 | 9.6 | 3.95 | 2.43[d] |
| Fought fire | 25.6 | 9.7 | 15.9 | 4.83 | 3.29[c] |
| Removed fuel | 3.4 | 3.1 | 0.3 | 2.17 | 0.14 |
| Tried to extinguish | 5.3 | 2.8 | 2.5 | 2.49 | 1.00 |
| Went to fire area | 3.1 | 2.8 | 0.3 | 2.07 | 0.14 |
| Total | 70.2 | 33.5 | 36.7 | 6.01 | 6.11[c] |
| *N* | 184 | 101 | | | |
| Called fire department | 25.6 | 33.0 | 7.4 | 5.83 | 1.27 |
| Had others call fire department | 9.2 | 7.5 | 1.7 | 3.27 | 0.52 |
| Went to fire alarm | 3.8 | 3.8 | 0.0 | 0.0 | 0.0 |
| Pulled fire alarm | 1.9 | 1.6 | 0.3 | 1.65 | 0.18 |
| Total | 40.5 | 45.9 | 5.4 | 6.31 | 0.85 |
| *N* | 106 | 146 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.
[d]Critical ratios significant at or above the 5 percent level of confidence.

**TABLE 4.1.14** *Reasons Elicited from Occupants for Not Leaving the Fire Building*

| Reason | Participants Number | Participants Percent |
|---|---|---|
| Fight fire | 52 | 48.7 |
| Notify others | 7 | 6.5 |
| Blocked by smoke | 7 | 6.5 |
| Blocked by fire | 5 | 4.7 |
| Overcome by smoke | 5 | 4.7 |
| Search for fire | 3 | 2.8 |
| Needed help | 2 | 1.9 |
| Secure property | 2 | 1.9 |
| Afraid of fire spread | 2 | 1.9 |
| No fire in area | 1 | 0.9 |
| Help others | 1 | 0.9 |
| Does not know | 1 | 0.9 |
| No response to fire department | 1 | 0.9 |
| Home | 1 | 0.9 |
| Return to area | 1 | 0.9 |
| Not reported | 16 | 15.0 |
| $N = 15$ | 107 | 100.0 |
| Range = 1–52 | Percent of participant population = 15.6 | |

occupants through smoke. The principal variables influencing an occupant's decision to move through smoke appear to be recognition of the location of the exit and thus of the travel distance, the appearance of the smoke, the smoke density, and the presence or absence of heat.[48,49] To achieve evacuation, occupants have moved through smoke, even for extended distances under conditions of extremely limited visibility at personal risk, and sometimes have been forced to turn back without completing the evacuation.[8,15,48,49]

Jin and Yamada[60] reported on a study involving 31 subjects (14 males and 17 females) traveling a maximum distance of 10.5 m in a corridor while exposed to smoke from smoldering cedar crib chips. The smoke extinction coefficient varied from 0.1 to 1.2 ($m^{-1}$). Subjects were also exposed to increasing heat from radiant heaters at the end of the corridor, where the mean temperature was 82°C. At five points in the corridor the subjects stopped and were asked mental arithmetic questions. Both walking speed in the corridor and mental arithmetic capability decreased as smoke density and radiant heat exposure increased.

Proulx and Fahy[24] in their questionnaire study of 382 employees in the1993 World Trade Center explosion and fire found that 94 percent of the respondents in Tower 1 and 70 percent of the respondents in Tower 2 moved through smoke. In addition, the study reported that approximately 75 percent of these individuals turned back during their evacuation because of smoke, crowding, locked doors, breathing difficulty, fear, and poor visibility. It was also reported that some occupants continued to move through smoke, even when they perceived the smoke to be worsening and believed that they may have been moving toward the fire.

Table 4.1.15 compares the distance moved through smoke for the 1316 persons in the British study and the 322 persons in the U.S. study. Sixty percent of the British study population and 62.7 percent of the Project People participants reported that they moved through smoke. It is thus apparent that building occupants will move through smoke in an evacuation process. An important variable may be the smoke density or the visibility distance of the occupants during the evacuation process.

Table 4.1.16 presents the visibility distance reported by the British and U.S. occupants as they moved through smoke while evacuating a fire building. They reported their movement

**TABLE 4.1.15** *Comparison of the Distance Moved through Smoke for British and U.S. Populations*

| Distance Moved (ft) | British (percent, $P_1$) | U.S. (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1-P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| 0–2 | 3.0 | 2.3 | 0.7 | 1.02 | 0.69 |
| 3–6 | 18.0 | 8.4 | 9.6 | 2.23 | 4.30[c] |
| 7–12 | 30.0 | 17.1 | 12.9 | 2.71 | 4.76[c] |
| 13–30 | 19.0 | 45.5 | 26.5 | 2.62 | 10.11[c] |
| 31–36 | 5.0 | 2.0 | 3.0 | 1.25 | 2.40[d] |
| 37–45 | 4.0 | 4.1 | 0.1 | 1.19 | 0.08 |
| 46–60 | 5.0 | 11.0 | 6.0 | 1.47 | 4.08[c] |
| 60+ | 15.0 | 9.6 | 5.4 | 2.10 | 2.57[d] |
| | 1316 | 322 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.
[d]Critical ratios significant at or above the 5 percent level of confidence.

**TABLE 4.1.16** *Comparison of the Visibility Distance for the British and U.S. Populations When Moved through Smoke*

| Visibility Distance (ft) | British (percent, $P_1$) | U.S. (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1-P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| 0–2 | 12.0 | 10.2 | 1.8 | 1.99 | 0.90 |
| 3–6 | 25.0 | 17.2 | 7.8 | 2.65 | 2.94[c] |
| 7–12 | 27.0 | 20.2 | 6.8 | 2.73 | 2.49[d] |
| 13–30 | 11.0 | 31.7 | 21.7 | 2.24 | 9.69[c] |
| 31–36 | 3.0 | 2.2 | 0.8 | 1.03 | 0.78 |
| 37–45 | 3.0 | 3.7 | 0.7 | 1.08 | 0.65 |
| 46–60 | 3.0 | 7.4 | 4.4 | 1.21 | 3.64[c] |
| 60+ | 17.0 | 7.4 | 9.6 | 2.24 | 4.20[c] |
| | 1316 | 322 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.
[d]Critical ratios significant at or above the 5 percent level of confidence.

through smoke under relatively high smoke density conditions, with visibility under 12 ft (3.7 m) for 64 percent of the British population and for 47.6 percent of the U.S. population.

Visibility distance for the British and U.S. populations at the time participants were forced to turn back is presented in Table 4.1.17. Comparison with Table 4.1.16 reveals that very few participants turned back when they could see more than 31 ft (9.4 m). The greater percentage of participants turned back at shorter visibility distances. When the visibility distance was below 12 ft (3.7 m), 91 percent of the British study population and 76.4 percent of the U.S. study population turned back (see Table 4.1.17).

Proulx[61] in the study of the occupants' response to a fire in a 25-story high-rise apartment building received 137 questionnaires returned, with 68 percent of the occupants over 60 years of age. Of the occupants, 114, or 83 percent, attempted to evacuate during the fire and 96, or 84 percent, of those attempting to evacuate moved through smoke. Forty-five percent of those moving through through smoke indicated they could see "nothing at all" or "little," and 30 percent said they could see 12–15 m in the corridor. Of the 114 occupants who attempted to evacuate, 61, or 54 percent, were successful and 53, or 46 percent, were unsuccessful due to the smoke conditions in the stairs or corridors. Relative to the 53 unsuccessful occupants, 29, or 55 percent, returned to their own apartments and 24, or 45 percent, sought refuge in other apartments.

Heskestad and Pederson[62] have reported on five large "escape through smoke" experiments involving more than 300 persons with various wayguidance systems. In all of these experiments, the visibility was less than 3 m due to the induced smoke conditions. Two of the experiments involved the test situation modeled on a ship staircase and a ship or hotel corridor. One of these experiments involved an emergency training mock-up, one experiment used a corridor in a healthcare facility, and

**TABLE 4.1.17** *Comparison of the Visibility Distance for the British and U.S. Populations Relative to the Turn Back Behavior*

| Visibility Distance (ft) | British (percent, $P_1$) | U.S. (percent, $P_2$) | $P_1 - P_2$ | $SE^a_{P_1-P_2}$ | $CR^b$ |
|---|---|---|---|---|---|
| 0–2 | 29.0 | 31.8 | 2.8 | 5.31 | 0.53 |
| 3–6 | 37.0 | 22.3 | 14.7 | 5.57 | 2.64[c] |
| 7–12 | 25.0 | 22.3 | 2.7 | 5.02 | 0.54[c] |
| 13–30 | 6.0 | 17.6 | 11.6 | 3.07 | 3.78[c] |
| 31–36 | 0.5 | 1.2 | 0.7 | 0.90 | 0.77 |
| 37–45 | 1.0 | 0.0 | 1.0 | 1.10 | 0.91 |
| 46–60 | 0.5 | 4.7 | 4.2 | 1.16 | 3.62[c] |
| 60+ | 1.0 | 0.0 | 1.0 | 1.10 | 0.91[c] |
| | 570 | 85 | | | |

[a]Standard error.
[b]Critical ratio.
[c]Critical ratios significant at or above the 1 percent level of confidence.

one experiment used portions of a passenger ferry. Variables measured during the experiments were the occupants time to travel through the experimental facility with the number of incorrect decisions made during the travel. These experiments found that tactile and audible wayguidance systems appear to be as suitable as the visible systems in assisting the individuals movement through smoke.

Jin[63] has reported on numerous studies involving the effectiveness of guidance sign systems with human subjects in smoke environments. Improvements resulting from these experiments include a pictorial exit sign, flashing exit lights, and a flashing row of lights at floor level indicating the direction of egress travel. The flashing row of lights was effective in a smoke level of 1.01/m with the spacing of the lights at 0.5 m.

## HANDICAPPED OR IMPAIRED OCCUPANTS

Fire problems involving occupancies designed for permanently or temporarily disabled persons, such as nursing homes and hospitals, appear to be matched on the basis of building design, adequate staff training, and ability to protect the occupants in place until evacuation is possible. An extensive study of human behavior in healthcare facilities[57] indicated that the nursing staff performed their professional roles toward their patients even when they were at risk.

The few fires studied involving handicapped persons in occupancies other than healthcare facilities have primarily been in residential occupancies. In two of these cases, handicapped individuals were helped by other occupants to evacuate successfully. One instance involved a wheelchair user[48] and the other a blind person.[64]

Handicapped people may have a variety of limitations that increase their risk in a fire: sensory problems, such as deafness and blindness; mobility problems that may entail the need for a wheelchair; and intellectual problems, such as mental retardation. Many handicapped persons with mobility problems also are concerned about their personal risk in high-rise office and residential buildings where the use of elevators is not allowed in a fire. In such situations, adequate areas of refuge must be provided for handicapped, as well as nonhandicapped, occupants.[65]

In their reports of the explosion and fire in the World Trade Center on February 26, 1993, Isner and Klem[66,67] indicated that when the explosion occurred at approximately 12:18 p.m., normal power was lost and the emergency generators failed about 20 min later; all remaining power to the World Trade Center complex was disconnected at approximately 1:32 p.m. Thus, the simultaneous evacuations of both able and disabled occupants from Towers 1 and 2 were conducted in darkness with varying smoke conditions in the stairways. These simultaneous evacuations may have involved the largest number of occupants and the longest evacuation times of any fire-induced evacuations of buildings in the United States.

Juillet,[68] in one of the first documented studies of this type, reported on the interview study of 27 occupants with disabilities who were evacuated from one of the two towers in the World

Trade Center during the explosion and fire of February 26, 1993. The impairments of the interviewees included 14 with mobility impairments, 3 with sight or hearing impairments, 3 who were pregnant, 2 with cardiac conditions, and 7 with respiratory conditions. Juillet[68] indicated that the total disability population in both Towers 1 and 2 at the time of the incident was believed to be between 100 and 200 persons, approximately 100 of whom had been previously identified. The average evacuation time of the 27 study participants was 3.34 hr, with evacuation times reportedly ranging from 40 min to over 9 hr. The predominant means of evacuation was through the stairs with assistance from other evacuees or emergency personnel. The altruistic behavior seen in many fire incidents with large populations[47,48,69] appeared to have been exhibited in this fire incident in relation to the disabled occupants as reported by Juillet.

> However, in the absence of communications by authorities, they gladly accepted assistance—from colleagues and even from complete strangers—in evacuating. These caring groups of people who assisted the disabled protected their 'charges' until they were safely evacuated and moved away from the building.[68]

The Fire Safety Engineering Research and Technology (SERT) Centre at the University of Ulster has completed the most extensive and detailed analytical and experimental studies of the evacuation capabilities of impaired individuals. Boyce, Shields, and Silcock conducted a series of studies in Northern Ireland to determine the number and characteristics of impaired persons who may be expected to frequent public buildings and to determine the capabilities of these persons to complete an evacuation. The initial study determined the number and types of impaired persons expected to occupy public assembly occupancies.[70] This study found that 12 percent of the mobile population of Northern Ireland out in public are impaired persons and 2 percent of these impaired persons require assistance. Table 4.1.18 presents the number of impaired adults and children by their degree of mobility expressed as a percentage of the total mobile population. Table 4.1.19 illustrates the impaired persons in public who have experienced evacuation difficulties as percentages of the total mobile population. Table 4.1.20 indicates the involvement of impaired persons in social and recreational occupancies relative to their degree of mobility.

Additional data presented in this study involved the frequency with which impaired persons go out in public. The prevalence of the type of impairment among the impaired population attending theaters, concert halls, motion picture theaters, sports stadiums, leisure centers, hotels, and lodging occupancies was reported. In addition, data was presented relative to the types of impairment among impaired adults who live in communal facilities and go out for meals and drinks, and for adults who are employed. The perceived value of this information and data relative to the application of performance codes was stated in the following manner:

> The information provided in this analysis has important implications for characterizing building occupancies. It establishes that public buildings are frequented by a significant number of disabled people and that the nature of their disabilities and how well they can be expected to evacuate without assistance during an emergency will be a function of the use of the building or part of the building. Characterizing buildings and characterizing occupants as required by performance-based codes, are not mutually exclusive activities a fact that has not yet percolated through the design professions.[71]

The second study by Boyce, Shields, and Silcock[72] involved experimental observations and measurement of the movement of impaired persons on a horizontal corridor, inclined

**TABLE 4.1.18** *Number of Disabled Adults and Children Who Go Out by Degree of Mobility, Expressed as Percentages of the Total Mobile Population, i.e., Able-Bodied People and Mobile Disabled People, N. Ireland*

| | Adults | | | Children | | | Total (adults and children) | | |
|---|---|---|---|---|---|---|---|---|---|
| Disability | Unassisted | Assisted | Total | Unassisted | Assisted | Total | Unassisted | Assisted | Total |
| Locomotion | 6.0 | 1.6 | 7.6 | 0.2 | 0.1 | 0.3 | 6.2 | 1.7 | 7.9 |
| Wheelchair users | 0.05 | 0.09 | 0.14 | — | — | — | 0.05 | 0.09 | 0.14 |
| Zimmer/rollator user | 0.13 | | | — | — | — | 0.13 | | |
| Walking stick/crutch | 1.27 | 1.52 | 6.91 | — | — | — | 1.27 | 1.52 | 6.91 |
| No aid | 3.99 | | | — | — | — | 3.99 | | |
| Reaching and stretching | 1.8 | 0.8 | 2.6 | 0.0 | 0.0 | 0.1 | 1.8 | 0.8 | 2.6 |
| Dexterity | 2.2 | 0.9 | 3.0 | 0.1 | 0.0 | 0.1 | 2.2 | 0.9 | 3.1 |
| Seeing | 2.0 | 0.9 | 2.9 | 0.04 | 0.04 | 0.2 | 2.1 | 0.9 | 3.0 |
| Blind | 0.02 | 0.05 | 0.06 | 0.0 | 0.0 | 0.01 | 0.02 | 0.05 | 0.07 |
| Hearing | 4.2 | 0.8 | 5.0 | 0.1 | 0.1 | 0.2 | 4.3 | 0.9 | 5.2 |
| Deaf | 0.1 | 0.1 | 0.1 | 0.0 | — | 0.0 | 0.1 | 0.1 | 0.1 |
| Mental | | | | | | | | | |
| Behavioral | 2.0 | 0.7 | 2.7 | 0.3 | 0.2 | 0.4 | 2.3 | 0.9 | 3.2 |

Note: Percentages for each disability do not sum to percent provided of the mobile population since many individuals have more than one disability. Percentages for wheelchair users and walking aid users do not sum to total since some data is missing.

Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Prevalence, Type, and Mobility of Disabled People," *Fire Technology,* 35, 1, 1999, p. 41.

TABLE 4.1.19 *Number of Disabled Adults Who Go Out and Experience Difficulty, Expressed as Percentages of Total Mobile Population of N. Ireland*

| Action | Go Out Unassisted Degree of Difficulty | | | Assisted Degree of Difficulty | | | Total Degree of Difficulty | | |
|---|---|---|---|---|---|---|---|---|---|
| | Some | Great | Impossible | Some | Great | Impossible | Some | Great | Impossible |
| Go up and down stairs | 2.4 | 1.1 | 0.2 | 0.2 | 0.6 | 0.2 | 2.59 | 1.69 | 0.43 |
| Climb outside steps | 1.5 | 0.8 | 0.2 | 0.3 | 0.4 | 0.2 | 1.81 | 1.14 | 0.40 |
| Cross door saddles | 0.1 | 0.1 | 0.03 | 0.2 | 0.1 | 0.01 | 0.32 | 0.13 | 0.04 |
| Go through doors | 0.1 | 0.03 | 0.01 | 0.1 | — | 0.01 | 0.15 | 0.03 | 0.02 |
| Turn door knobs | 0.3 | 0.1 | 0.03 | 0.2 | 0.07 | 0.05 | 0.43 | 0.13 | 0.08 |

Note: Since these percentages are based on adults only, the actual percentages of the mobile population in N. Ireland who experience difficulty may be higher.
Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Prevalence, Type, and Mobility of Disabled People," *Fire Technology*, 35, 1, 1999, p. 42.

TABLE 4.1.20 *Extent of Involvement of Disabled Adults and Children in Various Social and Recreational Activities by Degree of Mobility*

| Activity | Adults | | | Children | | | Totals | | |
|---|---|---|---|---|---|---|---|---|---|
| | Unassisted | Assisted | Total | Unassisted | Assisted | Total | Unassisted | Assisted | All |
| Participates in theatre, i.e., opera, musicals, ballet, cinema | 9,756 (6.5) | 2,514 (9.6) | 12,270 (7.0) | 1,028 (14.0) | 387 (7.3) | 1,415 (11.3) | 10,784 (6.9) | 2,901 (9.5) | 13,685 (7.3) |
| Goes shopping[a] | 1,532 (58.5) | 2,233 (40.0) | 3,765 (40.1) | 153 (81.0) | 53 (28.0) | 206 (75.7) | 2,235 (79.6) | 1,330 (23.5) | 3,565 (42.1) |
| Participates indoor sport/ spectates sport | 13,161 (8.9) | 1,006 (4.0) | 14,167 (8.1) | 3,205 (44.0) | 1,084 (20.5) | 4,289 (3.4) | 16,366 (10.5) | 2,090 (6.8) | 18,456 (9.9) |
| Attends ordinary social club | 8,052 (5.4) | 898 (3.6) | 8,950 (5.1) | — — | — — | — — | 8,052 (5.4) | 898 (3.6) | 8,950 (5.1) |
| Stayed in hotel/ other holiday accommodation | 40,220 (27.0) | 4,437 (17.6) | 44,657 (25.6) | — — | — — | — — | 40,220 (25.7) | 4,437 (14.5) | 44,657 (23.9) |
| Goes out for meals/drinks[a] | 1,318 (50.3) | 2,032 (36.4) | 3,350 (40.9) | — — | — — | — — | 1,277 (45.5) | 2,032 (35.8) | 3,350 (39.6) |
| Is employed | 18,896 (12.7) | 229 (0.9) | 19,125 (11.0) | — — | — — | — — | 18,896 (12.1) | 229 (0.7) | 19,125 (10.2) |
| Attends ordinary school | 350 (0.2) | 0 (0.0) | 350 (0.2) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 350 (0.2) | 0 (0.0) | 350 (0.2) |
| Attends college of further education | 316 (0.2) | 0 (0.0) | 316 (0.2) | 0 (0.0) | 0 (0.0) | 0 (0.0) | 316 (0.2) | 0 (0.0) | 316 (0.2) |

[a]Asked of disabled persons living in communal establishments only.
Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Prevalence, Type, and Mobility of Disabled People," *Fire Technology*, 35, 1, 1999, p. 44.

ramps, and stairs. Observations included the velocity of movement, rest periods required, assistance required, and the physical aids used relative to their degree of mobility impairment. One hundred seven persons (54 males and 53 females, ages 20 to 85) completed the horizontal corridor without assistance. The velocity of this population relative to the mobility impairment is presented in Table 4.1.21. Sixteen of the manual wheelchair users needed assistance to traverse the 50-m long corridor at the 90° turn, 8 m from the starting point. Only 34 individuals were capable of participating in the stair movement studies involving ascent and descent travel, with 30 of these without assistance and 4 with assistance, including three blind persons.

In general the movement velocity was slightly faster in descent travel on ramps, while on the stairs the ascent movement

**TABLE 4.1.21** *Speed (m/s) on Horizontal by Presence/Absence of Locomotion Disability and Walking Aid—Unassisted Ambulant*

| Subject Group | Mean (m/s) | Standard Deviation (m/s) | Range (m/s) | Interquartile Range (m/s |
|---|---|---|---|---|
| All disabled (*n* = 107) | 1.00 | 0.42 | 0.10–1.77 | 0.71–1.28 |
| With locomotion disability (*n* = 101) | 0.80 | 0.37 | 0.10–1.68 | 0.57–1.02 |
| No aid (*n* = 52) | 0.95 | 0.32 | 0.24–1.68 | 0.70–1.02 |
| Crutches (*n* = 6) | 0.94 | 0.30 | 0.63–1.35 | 0.67–1.24 |
| Walking stick (*n* = 33) | 0.81 | 0.38 | 0.26–1.60 | 0.49–1.08 |
| Walking frame or Rollator (*n* = 10) | 0.57 | 0.29 | 0.10–1.02 | 0.34–0.83 |
| Without locomotion disability (*n* = 6) | 1.25 | 0.32 | 0.82–1.77 | 1.05–1.34 |

Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Capabilities of Disabled People Moving Horizontally and on an Incline," *Fire Technology,* 35, 1, 1999, p. 54.

was faster, as indicated in a comparison of Table 4.1.22 and Table 4.1.23. These authors indicated the following findings from these experiments:

> The abilities of disabled people cover a wide spectrum with respect to movement on horizontal and inclined planes. Given the significant differences in the capabilities of those using different mobility aids and the inherent differences in their spatial requirements, it is suggested that, for evacuation and modeling purposes, they be considered separately.
>
> Escape times are usually determined from characteristic travel speeds coupled with premovement times. From this study it is apparent that, for some disabled people, it may also be necessary to include periods of rest and time to negotiate changes in direction. This paper's findings should help designers derive characteristic times for disabled people traversing any typical escape route.
>
> The detailed observations made during the movement studies suggest that, in designing accessible escape routes, more attention needs to be focused on the real, rather than the perceived needs of disabled people. Consideration should be given to the nature and position of support systems such as handrails, and the positioning of doors in escape routes, since these will influence the progress and the flight behaviors of some disabled occupants.[73]

The third study by Boyce, Shields, and Silcock[74] was an experimental study of door operation and egress. One hundred four mobility-impaired persons (54 male and 50 female, ages 25 to 85) participated in this study. Impairments of the participants involved 5 using crutches, 28 using a walking stick, 8 using a walker, and 63 using no mobility aids. The time to negotiate a standard single-leaf door with a clear width opening of 750 mm for these individuals is presented in Table 4.1.24 with the type of door operation and the closer force on the door leaf. In addition to the mobility impairments, other critical impairments for this action involved 45 persons with a minor reaching and stretching impairment and 58 persons with a dexterity impairment. Table 4.1.25 presents the failure rates and the time to negotiate the door for the seven manual wheelchair users. The manual wheelchair users in general took more time to push the door open than to pull the door open. It also took these wheelchair users three to four times longer than the mobility impaired persons to negotiate the door.

The fourth study by Boyce, Shields, and Silcock[75] was an experimental study to determine the ability of impaired persons to locate and read three types of exit signs: nonilluminated, internally illuminated, and light-emitting diode (LED) signs. The signs were placed in a clear atmosphere in a room, 2.3 m from the floor with a maximum viewing distance of 85 m. The distance which participants were able to read the exit signs was measured. A total of 118 impaired persons participated in this study, including 25 persons with a sight impairment. Table 4.1.26 presents the distance at which the participants could read the signs.

**TABLE 4.1.22** *Speed (m/s) on Stairs (Ascent) by Presence/Absence of Locomotion Disability—Unassisted Ambulant*

| Subject Group | Mean (m/s) | Standard Deviation (m/s) | Range (m/s) | Interquartile Range (m/s) |
|---|---|---|---|---|
| With locomotion disability (*n* = 30) | 0.38 | 0.14 | 0.13–0.62 | 0.26–0.52 |
| No aid (*n* = 19) | 0.43 | 0.13 | 0.14–0.62 | 0.35–0.55 |
| Crutches (*n* = 1) | 0.22 | — | 0.13–0.31 | 0.26–0.45 |
| Walking stick (*n* = 9) | 0.35 | 0.11 | 0.18–0.49 | |
| Rollator (*n* = 1) | 0.14 | — | — | — |
| Without disability (*n* = 8) | 0.70 | 0.24 | 0.55–0.82 | 0.55–0.78 |

Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Capabilities of Disabled People Moving Horizontally and on an Incline," *Fire Technology,* 35, 1, 1999, p. 64.

**TABLE 4.1.23** *Speed (m/s) on Stairs (Descent) by Presence/Absence of Locomotion Disability—Unassisted Ambulant*

| Subject Group | Mean (m/s) | Standard Deviation (m/s) | Range (m/s) | Interquartile Range (m/s) |
|---|---|---|---|---|
| With locomotion disability (*n* = 30) | 0.33 | 0.16 | 0.11–0.70 | 0.22–0.45 |
| No aid (*n* = 19) | 0.36 | 0.14 | 0.13–0.70 | 0.20–0.47 |
| Crutches (*n* = 1) | 0.22 | — | — | — |
| Walking stick (*n* = 9) | 0.32 | 0.12 | 0.11–0.49 | 0.24–0.46 |
| Rollator (*n* = 1) | 0.16 | — | — | — |
| Without disability (*n* = 8) | 0.70 | 0.26 | 0.45–1.10 | 0.53–0.90 |

Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Capabilities of Disabled People Moving Horizontally and on an Incline," *Fire Technology*, 35, 1, 1999, p. 65.

**TABLE 4.1.24** *Time (s) to Negotiate Door for Each Door Setting by Mobility Aid—Ambulant Disabled*

| | No Aid (*n* = 63) | | | Crutch Users (*n* = 5) | | Walking Stick Users (*n* = 28) | | | Walking Frame/Rollator Users (*n* = 8) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Closing Force (*N*) | Mean (s) | Standard Deviation (s) | Range | Mean (s) | Range | Mean (s) | Standard Deviation (s) | Range (s) | Mean (s) | Range |
| Push | | | | | | | | | | |
| 21 | 3.0 | 0.8 | 1.7–4.5 | 3.7 | 3.6–3.8 | 3.7 | 1.5 | 2.3–7.4 | 7.9 | 2.0–12.8 |
| 30 | 3.5 | 2.2 | 1.9–15.0 | 3.0 | 2.5–3.2 | 3.8 | 1.5 | 2.5–7.3 | 6.3 | 2.2–10.5 |
| 42 | 3.7 | 1.5 | 1.6–10.2 | 3.8 | 2.9–5.2 | 4.0 | 1.6 | 2.3–7.5 | 5.2 | 2.1–10.3 |
| 51 | 4.1 | 2.4 | 1.0–14.3 | 3.6 | 3.1–3.9 | 4.3 | 2.4 | 1.5–10.7 | 7.9 | 2.0–14.3 |
| 60 | 4.0 | 1.9 | 1.3–13.0 | 3.8 | 3.6–4.1 | 3.7 | 1.5 | 1.7–7.9 | 5.2 | 2.0–10.3 |
| 70 | 4.3 | 2.0 | 1.7–11.2 | 3.9 | 3.3–4.6 | 4.6 | 2.1 | 2.5–11.1 | 6.2 | 1.7–11.2 |
| Pull | | | | | | | | | | |
| 21 | 3.3 | 1.5 | 1.5–7.6 | 2.8 | 2.2–4.0 | 3.6 | 1.4 | 1.8–7.6 | 5.7 | 2.0–8.2 |
| 30 | 3.2 | 1.0 | 1.5–5.2 | — | — | 3.2 | 0.9 | 1.8–4.9 | 5.2 | 4.3–6.0 |
| 42 | 3.7 | 1.8 | 1.4–12.6 | 4.0 | 2.9–6.3 | 3.9 | 1.4 | 1.9–6.8 | 4.7 | 2.6–6.9 |
| 51 | 3.8 | 1.6 | 1.5–10.2 | 3.6 | 2.5–4.6 | 4.6 | 2.2 | 1.5–9.5 | 6.3 | 2.5–11.2 |
| 60 | 4.1 | 1.9 | 1.5–11.4 | 3.6 | 2.7–4.7 | 4.1 | 1.7 | 1.4–7.4 | 8.9 | 1.9–17.0 |
| 70 | 4.6 | 2.2 | 1.5–12.6 | 4.6 | 2.6–4.7 | 4.9 | 2.3 | 2.1–9.7 | 3.2 | 1.9–6.7 |

Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Capabilities of Disabled People to Negotiate Doors," *Fire Technology*, 35, 1, 1999, p. 73.

The LED signs appeared to be the most visible and legible by the impaired persons with and without a sight impairment.

In a related study, Shields[76] observed that wheelchair users and mobile participants did not impede each other in evacuation progress and wheelchair persons did not impede each other. Mobility-impaired persons with walkers did impede wheelchair users.

Klote, Alvord, Levin, and Groner[77] examined the design considerations needed to enable elevators in tall buildings to be utilized for the evacuation of disabled occupants. In the World Trade Center explosion and fire of 1993, the loss of power in both Towers 1 and 2 (including emergency power) trapped occupants in elevators in both buildings.

Burns[23] indicated Tower 1 had 99 elevator cars, many of them occupied. When one 6 ft × 8 ft (1.8 m × 2.4 m) car was opened, nine occupants were found unconscious. It was estimated that they had been exposed to the smoke in the shaft for approximately 2 hr at the ninth floor. Sherwood[78] reported that one 9 ft × 12 ft (2.7 m × 3.6 m) elevator car was stuck for 6 hr at the 41st floor of Tower 2 with 72 occupants (62 elementary school children and 10 adults).

NFPA *101*[2] in the 1991 edition of the Code permitted the use of elevators with fire fighter service from areas of refuge which were also specified in this edition. In 1997 the *Life Safety Code* permitted the use of a fire fighter service elevator with special features to be used as a second means of egress from towers with specifications on the occupant load of the tower, the provision of automatic sprinklers, the egress arrangement, and capacity.

A study of a number of evacuation drills in high-rise office buildings in Canada indicated that approximately 3 percent of the occupants were unable to use the stairs due to permanent or temporary conditions limiting their mobility.[79] The study

**TABLE 4.1.25** *Percentage Failure and Time (s) to Negotiate Door for Each Door Setting—Manual Wheelchair Users*

| Closing Force Leading Edge (*N*) | No. of Failures (percent) | No. successful (percent) | Mean (s) | Median (s) | Range |
|---|---|---|---|---|---|
| Push (*n* = 7) | | | | | |
| 30 | 1 (14.3) | 6 (85.7) | 13.1 | 7.4 | 3.6–39.0 |
| 42 | 1 (14.3) | 6 (85.7) | 13.3 | 10.7 | 3.6–36.0 |
| 51 | 2 (28.6) | 5 (71.4) | 10.0 | 7.4 | 3.6–20.5 |
| 60 | 2 (28.6) | 5 (71.4) | 10.5 | 10.5 | 3.5–17.4 |
| 70 | 2 (28.6) | 5 (71.4) | 11.6 | 6.7 | 3.6–26.3 |
| Pull (*n* = 7) | | | | | |
| 30 | 2 (28.6) | 5 (71.4) | 13.5 | 11.3 | 3.7–34.0 |
| 42 | 3 (42.9) | 4 (57.1) | 12.8 | 6.8 | 3.8–34.0 |
| 51 | 3 (42.9) | 4 (57.1) | 10.5 | 7.0 | 3.8–24.0 |
| 60 | 5 (71.4) | 2 (28.6) | 4.2 | 4.2 | 2.8–4.6 |
| 70 | 5 (71.4) | 2 (28.6) | 4.3 | 4.3 | 3.7–5.0 |

Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Capabilities of Disabled People to Negotiate Doors," *Fire Technology,* 35, 1, 1999, p. 74.

**TABLE 4.1.26** *Distance (m) at Which Subjects Can Read Exit Signs by Presence/Absence of Seeing Disability*

| Type of Sign and Subject Group | Mean (m) | Median (m) | Standard Deviation (m) | Range (m) | Interquartile Range (m) |
|---|---|---|---|---|---|
| Non-illuminated exit sign | | | | | |
| All disabled (*n* = 105) | 13.3 | 15.0 | 3.1 | 1.0–15.0 | 12.0–15.0 |
| With seeing disability (*n* = 25) | 11.4 | 12.0 | 4.0 | 1.0–15.0 | 9.7–15.0 |
| Without seeing disability (*n* = 80) | 13.7 | 15.0 | 2.7 | 6.0–15.0 | 15.0–15.0 |
| Illuminated exit sign | | | | | |
| All disabled (*n* = 118) | 14.2 | 15.0 | 2.7 | 1.0–15.0 | 15.0–15.0 |
| With seeing disability (*n* = 25) | 12.9 | 15.0 | 4.6 | 1.0–15.0 | 15.0–15.0 |
| Without seeing disability (*n* = 93) | 14.5 | 15.0 | 1.8 | 6.0–15.0 | 15.0–15.0 |
| LED sign | | | | | |
| All disabled (*n* = 83) | 14.6 | 15.0 | 1.6 | 5.0–15.0 | 15.0–15.0 |
| With seeing disability (*n* = 23) | 14.0 | 15.0 | 2.6 | 5.0–15.0 | 15.0–15.0 |
| Without seeing disability (*n* = 60) | 14.7 | 15.0 | 1.2 | 7.0–15.0 | 15.0–15.0 |

Source: K. E. Boyce, T. J. Shields, and G. W. H. Silcock, "Toward the Characterization of Building Occupancies for Fire Safety Engineering: Capabilities of People with Disabilities to Read and Locate Signs," *Fire Technology,* 35, 1, 1999, p. 83.

population included occupants with heart conditions and individuals recovering from surgery, other illnesses, and accidents.

## FIRE EXIT DRILLS

Well-marked exits do not ensure life safety during a fire. Exit drills are necessary so that occupants will know how to make an efficient and orderly escape according to NFPA *101,* which contains detailed information on exit drills in individual occupancies. Exit drills are required in schools, board and care facilities, and healthcare facilities, and are common in industries with high hazards. Employee training and drills are required in assembly, hotel, mercantile, and large business occupancies. Some form of exit drill should be conducted wherever or whenever possible to avoid confusion and ensure the evacuation of all occupants during a fire.[80] Personnel should be assigned to check exits for availability, search for stragglers, count occupants once they are outside the fire area, and control reentry into the building before it is safe.

This reentry behavior for rescue purposes of persons involved in fire incidents should be noted. In a study of 335 fire incidents involving 584 persons, it was found that 163 persons, approximately 28 percent of the study population, reentered the fire buildings following evacuation.[8] Approximately 10.5 percent of those persons who reentered the buildings did so to alert or assist other persons.

Determining when and what area to evacuate is probably the most important decision in a fire emergency. Any area at all affected by heat, flame, or smoke should be evacuated; in case of doubt, the entire building should be evacuated.

The fire loss prevention and control management staff are responsible for planning exit drills. Plans should be discussed with both middle and line management to ensure understanding and cooperation. If there is no fire loss prevention and control manager, the plant, facility, or building manager should assume this responsibility or assign it to a staff member.

All employees should recognize the evacuation signal and know the exit route they are to follow.[81] Upon hearing the signal, they should shut off equipment and report to a predetermined assembly point. Primary and alternative routes should be established, and all employees should be trained to use either route.[80,82]

The problem with audible evacuation signals is the conditioning of the population within the occupancy to ignore the signal due to numerous false alarms. An investigation of an apartment building fire found that the alarm system actuation to initiate evacuation behavior was ignored by many of the building occupants due to the conditioning effect of numerous prior false alarms: 44 percent of the building occupants believed the alarm signal was a false alarm.[83]

When employees are assembled, the manager or supervisor of each area should account for all personnel. Missing employees should be immediately reported to the fire loss prevention and control manager and responding fire department personnel so that search and rescue efforts can be initiated. Only trained fire-fighting search and rescue personnel with adequate protective equipment should be permitted to reenter an evacuated area.

After each exit drill, a meeting of the responsible managers should be held to evaluate the success of the drill and to solve any problems that may have arisen.

One significant improvement to the traditional concept of fire drills in educational occupancies was suggested by a study of fire drills conducted in such occupancies.[84] The concept of smoke drills has been established, whereby the occupants are instructed to move through the simulated smoke areas in a crouched position. Students have transferred the smoke drill concept to fire incidents in residential occupancies, with effective results. Obviously, the utilization of smoke drill training may be effective in a fire incident and should be used where applicable.

The timing of drills depends upon the nature of the operation in the facility. Generally, drills conducted a few minutes before the lunch break have been found to minimize loss of time and production. The frequency of drills should be determined by the degree of hazard present and by the complexity of shutdown or evacuation procedures.

If a facility does not maintain a security organization that is responsible for daily inspection of emergency exits and designated evacuation routes, one employee in each area should be assigned this task. Maintenance of doors, panic hardware, exit lights, and emergency illumination should be given high priority, and repairs must be made without delay.

Research has found that for multistory office buildings, a trained group of floor wardens is the most effective means of monitoring the evacuation of occupants.[80] Adequate training for floor wardens or other personnel is necessary and must be specifically developed to include the procedures of the emergency evacuation plan for the facility.

The lecture method has been used to convey the essential features of the emergency plan to employees in healthcare facilities.[82] However, it was also found that the emergency plan in the facility studied was too general and ambiguous.

The most serious problem with using building monitors is the turnover of personnel due to employee transfers, reassignments, or resignations. Effective evacuation planning and preparation should assign specific responsibilities to staff positions (rather than individuals) within an organization. This ensures continuity of performance despite personnel changes.

A content and time evaluation of fire drill behavior by staff in six nursing homes concluded that a training program of the most modest type can produce changes in both knowledge and behavior of evacuation and fire emergency procedures.[85] A total of 339 nursing home staff participated in the study that matched a group of 37 persons receiving the training with a control group of 49 persons not receiving the training. The high rate of personnel turnover, which appears to be rather typical in nursing home facilities, was noted. Following the presentation of the training program, staff members were evaluated by a written knowledge test, and their behavior was observed during the conduct of a drill of the emergency plan.

The evacuation signal should be familiar to all employees. Vocal alarm systems (VAS)[80,81] reduce the need for employee perception and recognition of a signal, because the system provides vocal communication to the areas designated for evacuation. NFPA *101* first recommended the use of the VAS in assembly occupancies in 1981. An evaluation of VAS systems in nine buildings found that familiarity with the system or initial activation did not significantly affect the egress behavior of populations.[80] In addition, the investigation determined the evacuation drills were valuable because they gave floor or area wardens an opportunity to rehearse their procedures.

The use of an alerting tone in the frequency range of 2000–4000 Hz for the VAS is recommended prior to the verbal announcement, which should be specific for the audience and the facility.[80,86]

## Healthcare Facilities Drills

Fire drills in healthcare institutions are usually conducted as a part of the orientation program for new employees. Later, the drills are supplemented with in-service training for the staff personnel, including the emergency procedures. Fire drills in many facilities are conducted once a month on each shift. The training for the drills typically involves instruction and practice for the staff personnel in the various means of moving nonambulatory patients, procedures for alerting the facility staff, and the method of notifying the fire department. Once or twice a year, many facilities have fire departments provide training in the operation of portable fire extinguishers. Some fire departments actually provide staff personnel with experience in the operation of extinguishers on external fires.

However, most healthcare facilities prefer to train their personnel. Most adopt the philosophy that it is the staff's responsibility to ensure the safe evacuation of patients initially to an area of refuge and then to the exterior if necessary. The control of the fire is limited to preventing the spread of heat and smoke by closing doors. This protects the occupants and inhibits or restricts the propagation of the smoke and heat throughout the facility. Staff personnel have effectively evacuated numerous patients under fire conditions or have protected the patients in their rooms by closing doors.[87]

Thus, the evacuation process may be considered in four sequential phases: (1) the personnel supply phase, (2) the patient preparation phase, (3) the patient removal phase, and (4) the rest and recovery phase.[88] This approach focuses on the occupants in the fire-threatened area and the patients in or adjacent to the fire area. Removing immediately threatened patients and closing doors to the room of fire origin and to adjacent patient rooms would be compatible with this four-phase approach to evacuation.

A detailed report on the fire evacuation organization, training, and drills involved in a 502-bed acute-care teaching hospital with 2500 employees has been published.[89]

In 1985, NFPA *101* included a new chapter devoted to the fire protection and life safety requirements for board and care facilities. That chapter requires the evaluation and classification of the population of the facility, according to their evacuation capability.

## Evaluating Fire Drill Plans

The ultimate evaluation of fire drill and emergency plans has two factors: (1) performance of the occupants in a fire incident, and (2) effectiveness of the behaviors used in accordance with the fire drills or the fire emergency plan. In a World Trade Center fire incident report,[22] building occupants tended to attempt to verify their beliefs about the threat of fire by physical clues, primarily smoke in the occupants' area. The report also indicated public address messages were not sufficient to alleviate spontaneous evacuations when occupants saw smoke on their floor. Further, occupant evacuation was reported (9th through 22nd floors) due to the perception and concern that a valid fire threat existed. In actuality, the fire did not require such an extensive evacuation.

Successful evacuation of personnel from the two floors above and below a fire in a 28-story high-rise college dormitory has been reported.[90] To allow free evacuation flow of the occupants down the stairways and allow fire department personnel to move up the stairs, stairs have been marked for occupant and fire department movement. The fire department movement stair has a red circle, 6 in. (152 mm) in diameter, on the door, and is also utilized for ventilation. The occupant stair is marked with a 6-in. (152-mm) green circle.

In the safe evacuation during a high-rise hotel fire with 190 guests, 110 guests were assisted by the fire department. The success of the evacuation was made possible by the hotel employees' fire safety education and practice of evacuation procedures.[91]

## SUMMARY

Behavior in fires can be understood as a logical attempt to deal with a complex, rapidly changing situation in which minimal information upon which to act is available. It is suggested that the goals of codes should be "reoriented to increase the likelihood of informed decisions being made by people in fires."[92] Examination of behavior in the Beverly Hills Supper Club fire led to the recommendation that "fire safety education should consider and be based on people's erroneous conceptions about distance being related to safety, and the time needed to escape from a fire emergency."[93] More than a decade of detailed systematic research on human behavior in fires has resulted in the following consensus[54] on the behavior of most persons:

> Despite the highly stressful environment, people generally respond to emergencies in a "rational," often altruistic manner, insofar as is possible within the constraints imposed on their knowledge, perceptions, and actions by the effects of the fire. In short, "instinctive panic" type reactions are not the norm.

The relationship between the physical and social environment in which behavior occurs is complex. The situation is complicated by the individual's perception of ambiguous fire cues, which is primarily influenced by the person's relevant training and previous fire experience, if any. It must be recognized that fire cues are a product of a rapidly changing dynamic process that is constantly altering the decisions of the building occupant. This dilemma has been summarized: "What is an appropriate action at one stage may be quite inappropriate a minute later."

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## NFPA Codes, Standards, and Recommended Practices

*Reference to the following NFPA codes, standards, and recommended practices will provide further information on human behavior and fire discussed in this chapter. (See the latest version of* The NFPA Catalog *for availability of current editions of the following documents.)*

*NFPA 72®, National Fire Alarm Code®*
NFPA *101®, Life Safety Code®*

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