58 Human Behavior in Fire

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Introduction

Human behavior in fire is at the core of all life safety projects completed by fire safety or fire protection engineers. A better understanding of how people respond to building emergencies can aid in safer building design; improved use or development of calculation tools used to ensure the level of safety afforded by these designs; and more effective emergency procedures, emergency communication systems, and pre-event emergency training for buildings and communities. The purpose of this chapter is to provide a basic understanding of human behavior in fire concepts and theory for use by engineers. The chapter contains the following aspects of human behavior in fire and other emergencies: a definition of human behavior in fire, including a discussion of the types of disciplines employed in the study of people in fires; a presentation on what human behavior in fire is not, including examples of disaster myths; an overview of the disaster-based decision-making process in fires and other emergencies; a discussion relating theory to practice (highlighting studies from fire events that support the decision-making theory); the identification of important factors that influence the decision-making process; and a conclusion highlighting what is missing in the field of human behavior in fire. Each section of this chapter will include an implications section that outlines the reasons why these ideas or theories are important for engineers to understand and incorporate.

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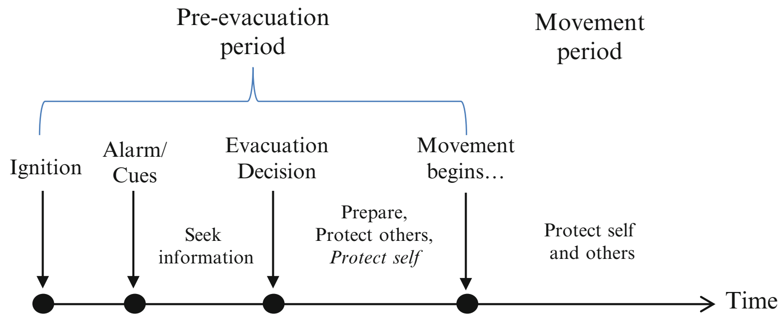
Definition of Human Behavior in Fire

Human behavior in fire is the study of human response, including people's awareness, beliefs, attitudes, motivations, decisions, behaviors, and coping strategies in exposure to fire and other similar emergencies in buildings, structures and transportation systems. The study of human behavior in fire is highly multidisciplinary, involving practitioners from the fields of engineering, architecture, computer science, mathematics, law, sociology, psychology, human factors, communications and ergonomics, to mention just a few. The primary focus of human behavior research and its translation into practice is to minimize the risk to people from fire. This is achieved by generating and collecting quantitative and qualitative data on human responses which can be used to develop human fire response theory.[1] A comprehensive theory of human response is key to improve current fire safety engineering design, performance based regulatory systems, egress-

[1] This definition of human behavior in fire was first presented in the brochure advertising the 2012 Human Behaviour in Fire Symposium, developed by consensus of program committee members (Interscience Communications).

M. Hurley (ed.), *SFPE Handbook of Fire Protection Engineering*,
DOI 10.1007/978-1-4939-2565-0_58,

Fig. 58.1 Timeline of a human response to a building fire emergency



related computational models and fire safety management.

The ultimate goal of improving life safety analyses in performance-based design is to develop a comprehensive theory of human fire response. Human behavior is complex and there is more work to be done to achieve this goal. A focus on case studies of specific building fires [1–3], and research on particular aspects of a fire evacuation has left the field of human behavior in fire with a series of partial-theories, rather than a comprehensive theory of human behavior in fire. As a result, human response to fires is often crudely categorized into two main periods: the pre-evacuation period[2] and the movement period, with little understanding of the behavioral processes that take place within each one. The pre-evacuation period estimates the time when ignition begins until the point when an individual or group begins purposive evacuation movement to a place of safety. The time period in which purposive movement to safety occurs is then considered the evacuation or movement period.

As shown in Fig. 58.1, and as will be presented throughout this chapter, the pre-evacuation and movement periods consist of additional sub-phases that the engineer should understand. For example, within the pre-evacuation period, at least three sub-phases can exist:

- The pre-alarm phase, which is the time from the point when fire ignition begins until the point when the building alarm initiates and/or building occupants are exposed to cues from the fire event (i.e., seeing smoke or being told about the fire event by a staff member)
- The evacuation decision-making phase, where building occupants are exposed to or seek out cues/information from the fire event and others in the building, and after processing this information, must decide whether or not it is necessary to protect themselves (e.g., evacuate)
- The protective action phase, whereby individuals engage in certain actions, e.g., gathering personal belongings or assisting others to prepare for evacuation that allows them to protect themselves or others before beginning evacuation.

These phases are important to understand, because in certain types of buildings or emergencies within a building, the pre-evacuation period can be significantly longer than the movement period in a building evacuation.

Additionally, the same types of decisions and actions can take place during the movement period, especially when people are faced with additional environmental cues.

The purpose of this chapter is to aid the engineer in understanding the current state of knowledge regarding the entire process of human behavior in fire emergencies. This process is important to understand because it is often the goal of fire safety or fire protection engineers (as well as fire marshals, authorities having jurisdiction, and other emergency responder personnel) to ensure that a particular structure or transportation system provides the appropriate

[2] Other terms have been used to express the pre-evacuation period, including pre-movement or pre-response.

level of life safety to its users. With this goal in mind, it becomes an almost impossible task to assess life safety (credibly or reliably) without understanding how the structure or transportation system will be used during a fire emergency. In a building, for example, an engineer must understand how the building occupants will respond to a fire in order to assess whether the building and the fire safety features provide an adequate level of safety during a fire emergency event. Therefore, this chapter focuses on communicating current understanding of human behavior in fire, including all phases of the human response, for use in fire safety and life safety analyses of structures and other systems.

Discarded Theories in Human Behavior in Fire

Before we can achieve an understanding of human behavior in fire, we must first discuss what human behavior in fire *is not*. This is critical since our understanding of human behavior in fire has direct implications to the engineering design process. Since behavior in fires has been studied since the 1950s (and for other disasters, earlier than that), certain claims have been made and then subsequently refuted as explanations of human behavior in fires. In this chapter, and elsewhere [4], these claims are labeled as disaster myths. In some cases, these disaster myths are true for a small minority of the population, but have become overgeneralized to hold for the entire population. In other cases, the disaster myth is completely invalid [5]. Three disaster myths will be discussed in this section: panic, disaster shock, and group mind. All three myths have been overgeneralized by society and the media to account for negative situations in some disaster scenarios, but, in reality, are very rare. These are chosen as discussion points in this section, since they have been used in the past to characterize occupant response to building fire disasters. These are not the only disaster myths promulgated by past events, nor the only disaster myths that may be promoted by future events.

Panic Behavior

The concept of panic is often used to explain the occurrence of multiple fatalities in fires. Representatives of the media and public officials often label various types of fire incident behavioral responses as panic [6, 7], often going so far as specifically asking about the presence of the behavior when interviewing disaster survivors [8].

According to most definitions, panic is a flight or fleeing type of behavioral response that also involves extravagant and injudicious effort. Panic is not necessarily limited to a single individual, and may be mimicked and adopted by a body of persons (i.e., mass panic or collective flight). Johnson describes panic as the following: "...selfish competition uncontrolled by social and cultural constraints—i.e., unregulated" and the breakdown of social order [9, 10]. Wenger et al. [11] includes a definition for "panic flight" as "the competitive mass behavior of individuals involved in fleeing from an imminent threat that results in increasing the danger to themselves and others". Quarantelli [7] characterizes panic not only as withdraw (or flight) behavior, but also as a behavior that encompasses a lack of consideration for others (i.e., competition).

Often, however, the concept of self-destructive or animalistic panic-type behavioral responses to fire incident stimuli, such as the presence of flames or smoke, has not been supported by the research on human behavior in fire incidents. As indicated by Sime [12], Quarantelli [13], and others [14–17], panic behavior in which the flight response is characterized by actual physical competition between the participants and personal injuries is rare. For example, Best studied extensive interviews with survivors of the Beverly Hills Supper Club fire (1977) to find that the staff and patrons of the club did not exhibit panic behavior, despite media accounts attributing the large loss of life to the phenomenon [18]. Also, several studies have been conducted on the 2001 World Trade Center Disaster (WTC), allowing researchers to assess the accuracy of the headline of a BBC News Online article, entitled: "Panic on the stairs" [8, 19]. Studies of both media accounts [20, 21] and survivor interviews [1, 22, 23] of this deadly terrorist attack revealed overall trends of calm and altruism. While there were reported situations of emotion, i.e., crying or being anxious or nervous about the situation, the majority of stories reported rational, orderly, and often times, delayed responses to the disaster event.

Therefore, the use of the concept of panic must be separated from the use of the terms *anxiety* or *fear*. These are natural emotions in emergency situations that do not necessarily lead to competitive, injudicious flight behavior (i.e., panic). Additionally, research has shown that survivors of fire emergencies (or other disasters) may mistakenly categorize their own behavior or the behavior of others as panic, whereas further description of actual actions barely reflect panic behavior [12, 24]. Ramachandran [25], in his review of studies on human behavior in fires in the United Kingdom, has developed the following conclusion relative to nonadaptive behavior:

> In the stress of a fire, people often act inappropriately but 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.

In reality, and in stark contrast to panic behavior, engineers should be aware that people's first assumption in many disasters, regardless of the intensity of the information perceived, is that nothing unusual is happening, and thus, no response is required. This phenomenon is known as normalcy bias [26–29]. It is our challenge, as engineers, to ensure that disaster victims (i.e., those who are in danger) become aware that a dangerous situation is taking place, and that they perceive personal risk. If not, they are unlikely to take actions to protect themselves from harm. Even in an event as large and intense at the 2001 WTC disaster, building occupants had to be convinced of the danger to which they were exposed, sometimes taking several minutes, before evacuating the building [30]. Additionally, in reference to the assumption of competition, engineers should acknowledge that altruistic behavior is more likely to occur. Researchers have found that even though disasters can cause shifts in the pre-existing situation, the breakdown of social order is rare [31, 32]. Many of the societal norms and social roles evident before the disaster carry over into the new, evolving situation. Therefore, occupants are likely to engage in pro-social behaviors, including helping others rather than competing with others, as they would do in non-disaster situations. Engineers should also be aware of these types of pro-social behavior, since they could lead to delays in the evacuation process, among other issues. The delays associated with altruist behavior, such as helping, should be accounted for in fire protection and emergency procedural design for buildings in the event of fire emergencies.

Disaster Shock

An additional disaster myth suggests that individuals who do not act irrationally (i.e., panic) are often immobilized by fear in emergency events [4, 33]. This myth creates an image of large numbers of individuals dazed or shocked; i.e., unable to cope with the new disaster-created situation at hand. This myth also extends into the disaster recovery stage, suggesting that the paralyzing shock created by the situation is followed by longer-term personal effects, often labeled as post-traumatic stress disorder, or PTSD. Although this may at first seem irrelevant to fire emergencies, since much of the research on disaster shock is reported in response to the natural or technological disasters, the myth of disaster shock is directly applicable to fire emergencies. In a building fire, the fire ignites and continues to grow as building occupants are made aware of the event and are encouraged to take protection (e.g., evacuate). In fires, different from a tornado event, for example, building occupants are warned about the event after it has already started to cause destruction. Thus, it is possible to assume in building fire events that individuals will go into shock in response to the fire, and thus rendering themselves incapable of evacuating on their own.

Researchers have found that following disasters, documented reports of disaster shock are rare. Melick [34], after reviewing disaster studies conducted between 1943 and 1983, found the following three conclusions regarding disaster shock: (1) Disaster shock occurs more frequently in sudden onset disaster events that are accompanied by little forewarning and extensive physical and social destruction; (2) Disaster shock affects a relatively small proportion of the population in any one event [7, 35]; and (3) Disaster shock usually occurs within the immediate postimpact period of a disaster, lasting no longer than a few hours or days [5]. Other researchers have shown that this phenomenon is rare and the state is usually short-lived [36].

Disaster researchers attempt to dispel this myth by explaining that disaster response behavior is often performed in an active manner [7]. Instead of waiting for assistance, in a dazed or disoriented manner, disaster victims are more likely to show considerable personal initiative, performing search and rescue activities, casualty care, and restoration of essential services even before emergency responders arrive on scene [11]. This kind of response was observed in the 2001 WTC disaster [30], where survivors were often the first individuals to respond to the needs of their coworkers, assisting them to reach safety before first responders could reach the upper floors. Belief in this assumption could cause engineers to focus more on emergency response officials and their role in evacuation. However, it is important for engineers to understand that building occupants will react in an emergency and proactively engage in their own (and others') safety. In turn, engineers must ensure sufficient and efficient evacuation routes and strategies to ensure safety for all occupants in the building.

One note that should be made here regarding this myth is the inability to interview those who perish from building fires, and the effect that this gap may have on our overall understanding of disaster shock. The fires and disaster fields may not fully understand the role of disaster shock in consequences (i.e., injuries and deaths), and therefore future research should focus on obtaining a better understanding of the circumstances of fatalities from fires (when possible). One way to obtain this type of data is to interview individuals who were physically with (or in contact with) the deceased during the fire emergency.

Group Mind

A third disaster myth is the oversimplification that the group is something other than the sum of individuals responses; i.e., that the group has a "mind" of its own when making decisions in a disaster [37]. Another way of thinking about group mind is the assumption that when a disaster occurs, individuals become a part of a group and the group (as a whole or as one entity) acts in response to the disaster. This assumption can also be characterized as mob behavior or herd behavior.

However, sociologists have stated that thinking that the group acts or thinks in a certain way is "often a serious oversimplification" [37]. Making this assumption can cause the engineer or researcher to be blinded by any diversity associated with the group, including individual characteristics, experiences, decision-making or behavior. If we make this assumption, we may then assign attributes to the group, including a mind, a sense of responsibility, a conscience, or even a lack of self-control (related to mass panic described above).

What is more likely, and what has been seen in actual disaster events, is that groups consist of a variety of different individuals. During disasters, it is more likely that groups engage in what is called "a division of labor" in that certain individuals take on particular roles based upon their experiences and/or relationships with others in the group, which complement each other and allow the group to function [37]. It is therefore important to understand the division of labor within the groups and the characteristics, experience, decision-making and behavior of the individuals within the group to truly understand human behavior in fire.

It should be noted; however, that there is extensive research in group dynamics and how groups "act" in disasters and building fires. This research will be described later in this chapter. Overall, it is neither the description of the group (only) nor the description of the individual (only) that is sufficient in understanding human behavior in fire. Instead, identifying both his/her attitudes toward the object (or issue at hand, in this case, the fire cue or cues) [38] and attitudes toward the group and others in the building (i.e., the processes of group dynamics) leads to the true understanding of human response in emergencies [37].

Engineering Implications of Disaster Myths or Why Should the Engineer Care?

Unfortunately, these disaster myths can have negative implications on fire safety in our society. Images of human behavior during disasters are often the basis for critical decisions made by engineers and other fire protection designers on building design requirements, emergency communications systems design and guidance, as well as emergency response procedures for fire events. The assumptions of irrationality or human frailty can inappropriately shape the way that engineers and emergency officials plan for response to fires in their buildings, as well as how evacuation models represent evacuation behavior during fires. Instead, it is important for engineers to understand the true needs of building occupants so that engineering and emergency procedural designs and methods more accurately reflect realistic occupant behavior during building fire events.

One example of how a disaster myth has had negative implications on fire safety is the influence of panic on emergency communication during fires [33]. The view that people would panic in response to an incident (and specifically to information describing the incident) has influenced both the notification procedures employed and the language used (by survivors) to report the exhibited behavior [39]. This assumption influenced a difficult and harmful cycle consisting of the following steps: people report that they panicked, emergency officials continue to believe that panic is a normal response, emergency information is withheld in the next disaster so that people do not panic, human response is delayed and inefficient, and the situation becomes more dire. Over the last 25 years, this point of view has been slowly replaced with the recognition that people need detailed and credible information as early as possible in order to initiate and inform their response. The availability of this information encourages people to accept the emergency procedures and to improve their familiarity with the required response, and later informs the decision-making process that determines their response. People need information in order to act. Detailed information by no means guarantees the desired response; however, without this information, an uninformed approach (ignorant of the conditions and the options available) is much more likely. It is now broadly accepted that depriving evacuees of information is more likely to lead to an inefficient and inappropriate response; e.g., misinterpreting the incident and the threat it poses, delaying response, engaging in an inappropriate response, and ignoring safe egress routes. During an incident, people will seek information regarding the nature of the incident and what they should do in response to it. Unfortunately, this information may not always be easy to find, reliable, consistent or accurate. It is critical that an information vacuum is avoided and that accurate, credible information is provided.

The previous section discussed the factors and theories that do not accurately describe human behavior during building fires and other events. Therefore, the following section will focus on describing the theory of human behavior in fires and the foundation upon which this and other related theories were built. This understanding of human behavior focuses on decision-making at the level of the individual, independent of whether the individual is on his/her own, a member of a group, or a member of a larger crowd during the emergency. Social psychological theories of decision-making during emergencies will be presented in the following section.

Social Psychological Theories of Human Behavior in Emergencies

Everyday, individuals go about their normal lives—attending meetings at work, watching movies at the local cinema, and shopping at the mall or the grocery store for all of their necessities. These are activities in which individuals have engaged so often that they have become routine in nature. When an emergency occurs, these activities may suddenly seem irrelevant. When an alarm is sounding or smoke is billowing into a room from an air conditioning duct, individuals are faced with a potentially new and unique situation where previous actions may no longer apply.

Under these new conditions, individuals are required to make a concerted effort to create meaning out of new and unfamiliar situations, often under time pressure. From this meaning, a set of actions, different from those that have become routine, must be created. Emergent norm theory (ENT), explains the process of meaning-making in the face of uncertain conditions [37], stating that in situations where an event occurs that creates a normative crisis (i.e., an event where the institutionalized norms [e.g., sitting at a desk and working] no longer apply), such as a building fire, individuals interact collectively to create an emergent situationally-specific set of norms to guide their future behavior. In other words, individuals must work together to redefine the situation and propose a new set of actions, which is the product of processes labeled "milling" and "keynoting".

Milling is a communication process whereby individuals come together in an attempt to define the situation, propose and adopt new appropriate norms for behavior, and seek coordinated action to find a solution to the shared problem at hand [40]. The group engages in both physical and verbal communication in order to ask the three following questions: (1) what happened? (2) what should we do? and (3) who should act first? (known as leadership selection) [41, 42]. Leaders emerge as keynoters, or those who advance suggested interpretations of the event or suggestions on what do to next [37, 43]. The consequences of the milling process are that individuals become sensitized to one another, that a common mood develops, and that a collective definition of the situation is decided upon that minimizes initial ambiguity [44]. Overall, in the face of new and uncertain situations, milling and the keynoting processes allow the group to define the situation and to propose next steps for alternative schemes of social action [40, 43, 44].

The new situation and next steps developed do not emerge in a social vacuum, however. Rather, individuals within a group bring with them certain aspects of the "normal" or non-emergency situation that influence decisions made in the new situation. First, individuals bring their "social stock of knowledge" to the situation. The social stock of knowledge consists of an individual's internal set of knowledge about the disaster (or disasters in general), experiences from previous disasters or building evacuations, and his/her relationships and roles within the building, especially those related to building fires and other types of disasters [45]. Second, individuals bring conventional norms, i.e., previous ways of acting within the building and/or society as whole, which are likely to influence the newly developed "next steps for action" during the current disaster situation [31].

Protective Action Decision Model—A Background

A decision-making model has been developed that extends and applies ENT's explanation of the meaning-making process in crises to disaster situations. The Protective Action Decision Model (PADM), which is based on over 50 years of empirical studies of hazards and disasters [28, 38, 46–49], provides a framework that describes the information flow and decision-making that influences protective actions taken in response to natural and technological disasters [50]. The model posits that cues from the physical environment (e.g., the sight of smoke) as well as information from the social environment (i.e., emergency messages or warnings), if perceived as indicating the existence of a threat, can interrupt normal activities of the recipient. Depending upon the perceived characteristics of the threat (e.g., what is going on and how dangerous is it?), indicative of the milling and keynoting processes described above, individuals will either seek additional information, engage in actions to protect people or property, perform actions to reduce psychological stresses, or resume normal activities [50]. In addition to perceptions of the threat, responses are also determined by the perceived feasibility of protective actions.

Before describing the stages of the PADM in detail, it is necessary to introduce the additional research and social models that it draws upon. Studies of social influence provide insight on the types of cues and information that affect behavior. Research and studies on the decision-making process shed light on the steps in which people engage to make decisions on their next course of action. Additionally, the PADM is based upon other theories and conceptual models that link together cues, cognitive processes and subsequent protection actions.

First, since people perceive information from both the physical and social environment, the PADM incorporates insights from social influence research. Theories of social influence posit that the actions of others and the risk communication process can influence human response in disasters. In ambiguous situations, the presence or actions of others helps to define what behavior is appropriate in a particular situation. If people are seen to be taking protective action, for example, moving to the same stair, others are likely to follow suit [51, 52]. Conversely, if people are not taking emergency action, others are also less likely to engage in emergency actions. Additionally, research has shown the influence of information (for example, warnings provided via emergency communication systems), on a person's beliefs, attitudes, and subsequent behavior [53, 54]. Aspects of the risk communication process, e.g., the source, the message, the channels, and the receiver characteristics (i.e., the receiver's perceptions of the credibility of the message, message comprehension, and channel preferences), can ultimately predict whether or not protective action is taken before or during crisis [38, 50].

As a decision-making model, the PADM also relies on behavioral decision theory. In a perfect world, in which those at risk behave like rational actors, decisions would be made based upon all of the necessary information available to the individual, which would be weighed based on costs and benefits of the various outcomes, leading ultimately to an optimal decision on the best course of action. More often, however, people lack the necessary information needed to make decisions, and they do not always search for additional information. Instead, they make decisions based on their beliefs about the situation, and many times, these beliefs can reflect poor understandings of the situation [55]. For example, in the Beverly Hills Supper Club fire when an employee took the stage and announced the presence of a fire, some of the patrons thought that the announcement was part of the evening's entertainment and in turn, remained in place rather than moving to the exits [18]. Decision scientists argue that people are often poor judges both of the likelihood of a disaster event and of the range and severity of impacts disasters can produce. This is because people use a variety of "quick and dirty" heuristics, which are simple rules or "cognitive short cuts" through which they judge a situation or event [56, 57]. One example of a heuristic that people employ is the availability heuristic, or judging the likelihood of an event based on the ease of recalling similar instances from memory [57, 58]. For example, people often think that deaths due to plane incidents are more frequent than deaths due to car accidents because they can recall more easily dramatic media coverage of large-scale plane crashes [59]. Another short cut, similar to social influence research, is an over-reliance on the actions of others [60]. In cases of procedural uncertainty, where individuals have little experience dealing with high-stakes decisions, individuals are likely to adopt the decision strategies of others and follow their behavior [60]. Unfortunately, the individuals who are followed may also be using cognitive short-cuts and taking inappropriate action. Heuristics can result in biased understandings of the situation, which may then be used to make sub-optimal decisions during a disaster.

Research in the area of judgment and decision-making under uncertainty also provides insights into the ways in which people make decisions on their next course of action based on their beliefs. "Rational-actor"-based research claims that individuals will optimize decision-making by weighing all options and choosing the best one [61, 62]. In situations of uncertainty or crisis, however, individuals or groups are unlikely to search for a large number of options due to significant time pressures [63–66]; limited mental resources (e.g., when they are under stress) [67–69]; or if they perceive themselves as experienced in or knowledgeable concerning recommended protective procedures [56, 70]. In situations with greater time pressure, dynamic conditions, and ill-defined goals [56], all of which are likely to characterize building emergencies, people are likely to *satisfice*. Satisficing [67, 69, 71] is a method in which an individual chooses what s/he sees as a sufficient rather than optimal option, "not to find the best [option] but to find the first one that works" [56]. For highly trained and experienced individuals, for example, fire fighters, satisficing may in fact lead to quicker, more effective and appropriate decisions for the task at hand. The decision-making technique may be detrimental, however, for occupants who are less experienced in building fires, increasing their delay to safety or even leading to more severe consequences, like injury or death.

Finally, the PADM is based upon theories that link cues, cognitive (internal) processes, and subsequent protective action. Much of that research seeks to establish links between the perception of risk and the performance of protective action. Janis and Mann [72] developed the conflict model to describe the process of emergency decision-making. An individual's response to a warning is based upon his/her perception of the severity and immediacy of the threat, the perceived effectiveness of the possible protective action, and the possibility of gaining more information about the event and possible actions.

Mileti and Sorensen [38] developed a model that describes the influence of cognition on warning response. Whereas the PADM focuses on responses of people to various types of cues before or during a disaster, this model summarizes the determinants and consequences of public responses to disaster warnings. The warning response model outlines a process in which the receiver must hear, understand, believe, and personalize the warning message in order to respond in an appropriate way. The first stage of the process is perceptually receiving the alert or warning; Mileti and Sorensen [38] note that before anyone can respond to a message, they must receive it first. Once the warning is received, it must be understood, and in this instance, "understanding does not refer to correct interpretation of what is heard, but rather to the personal attachment of meaning to the message" [38]. For example, what does a flood warning mean to one person, versus another? The next stage involves whether the person believes the warning or not—involving whether they believe that the warning is authentic and the contents of the message are accurate. Finally, the last stage in the process before response is personalization. This is the stage in which people think of the warning in personal terms, in that they begin to consider the implications of the risk for themselves and others around them. If the individual has heard, understood, believed, and personalized the warning, s/he will then decide what to do about the risk. Mileti and Sorensen [38] do not discuss the decision-making process and subsequent actions in depth, but generally state that people do next what they think is best for them. An important part of this process is confirmation. In threat situations, people are constantly seeking new information to confirm prior information, whether from family, friends, neighbors, and co-workers, or from various media sources and authorities. Confirmation affects each stage of the warning process, in that it helps people to better understand warnings, believe them, personalize the risk, and make decisions.

Protective Action Decision Model—The Stages of Decision-Making

Although the PADM is similar to the Mileti and Sorensen warning response model, the PADM provides a more general framework that describes information flow and decision-making specifically in response to various types of cues that originate from natural and technological disasters [50, 73]. The PADM asserts that the process of decision-making begins when people witness cues from the disaster event. Individuals can encounter only one type of cue (for example, seeing smoke) or may be presented with a variety of different cues, for example, environmental cues, the behavior of others, and warning messages. Warning messages can consist of both official and unofficial messages; i.e., official messages are those that come from official warning providers (e.g., emergency managers in a building fire) and unofficial messages are those that come from unofficial sources, such as others in the building.

The introduction of these cues initiates a series of pre-decisional processes that must occur in order for the individual to perform protective actions. First, the individual must perceive or receive the cue(s). Then, s/he must pay attention to the cue(s). Finally, the individual must comprehend the cue(s). Comprehension means understanding the information that is being conveyed. If the message uses a different language or highly technical terms, comprehension will be difficult. Comprehension also refers to the development of an accurate understanding of environmental cues. For example, will the individual understand that the smoke s/he smells is coming from a building fire rather than from burnt toast in the kitchen?

People go into any disaster with widely varying pre-event perceptions or beliefs about the elements that go into a disaster—the event itself, the actions that they have taken (or should take) before the disaster occurs, and the individuals involved in the response to a disaster. The differences in these perceptions are important to understand because they often are predictors of the individuals' response behaviors when the disaster occurs. The PADM labels these pre-event perceptions as core perceptions or schemas and highlights as important three main core perceptions: perceptions of threat, perceptions of protective actions, and perceptions of stakeholders [73].

First, perceptions of environmental threats include people's beliefs about the probability and consequences of certain types of disasters as well as their expectations about personal impacts, including death, injury, property damage, and disruption of daily activities (i.e., work, school, shopping, etc.). These can vary from individuals' beliefs that they are very unlikely to be involved in any type of disaster to individuals' severe worry or dread that the next disaster is coming specifically for them. Also associated with perceptions of environmental threats is what Lindell and Perry call "the degree of hazard intrusiveness" [73]. This refers to how often individuals are personally concerned with disaster consequences, the time they spend talking about disasters, and the amount of information they receive (passively) about hazards and disasters.

The second pre-event perception includes people's perceptions of protective actions; i.e., the actions that they can take to prepare for a disaster. Essentially, this perception captures individuals' attitudes about engaging in preparatory actions before a disaster occurs. This can also vary widely, from individuals taking no preparatory action at all and believing that these types of actions are not necessary to individuals taking extensive preparation in their homes and/or work places.

The third pre-event perception consists of individuals' perceptions toward stakeholders in a disaster. Stakeholders in a disaster can be authorities (i.e., federal, state or local government), evaluators (e.g., scientists, universities, medical professionals), watchdogs (e.g., news media), industry/employers, and individuals themselves (i.e., in their homes or places of work). Here, it is important to understand the ways in which people perceive stakeholders in terms of three factors: their expertise about disasters (in this case, fires), trustworthiness, and responsibility when a disaster or building fire takes place. This pre-event perception is more applicable to community-based disasters, such as hurricanes or tornadoes, but could be applied to fires in instances where, for example, building occupants do not trust warning information provided by a building manager.

All three of these perceptions have been shown in research to vary from individual to individual involved in the disaster situation. More importantly, these factors (among others) have been linked to the decisions that individuals make in disasters, and in turn, their protective actions (discussed below).

After the three pre-decisional processes are completed and the three core perceptions are activated (i.e., it is understood that there are differences among individuals in these three areas), the decision-making model consists of a series of five questions [50]:

- Is there a real threat that I need to pay attention to? [If yes, then the individual believes the threat]
- Do I need to take protective action? [If yes, then the individual decides that s/he needs to take protective action]
- What can be done to achieve protection? [The individual begins searching for possible protective action strategies]
- What is the best method of protection? [The individual chooses one of the action strategies developed in the previous stage and develops a protective action strategy or plan]
- Does protective action need to be taken now? [If yes, the individual follows the plan developed in the previous stage]

Individuals must "answer" each question in order to proceed through the perceptual-behavioral sequence, in which the outcome of the process is the performance of a behavioral action. A graphic of the process is shown in Fig. 58.2.

The first stage of the decision model involves the issue of risk or threat identification. If the individual perceives, pays attention to, and comprehends cues associated with an event, s/he first asks "Is there a real threat that I should pay attention to?" In this stage, according to Lindell and Perry, the individual decides if there is actually something occurring that may require her action, sometimes referred to as warning belief [74], "but this term unnecessarily excludes people's reactions to environmental cues so the term *threat belief* is generally more appropriate" [50]. This stage corresponds to the phase in ENT in which members of a population realize that the norms and behaviors for "stable times" no longer apply [37]. If the individual's answer is yes, then s/he is said to believe the threat, and s/he subsequently moves on to consider the next question in the process.

The second stage of the decision model is referred to as risk assessment. Research has shown that a person's perception of personal risk, or "the individual's expectation of personal exposure to death, injury, or property damage" is highly correlated with disaster response [50]. In this stage, also known as personalizing risk [38], the individual determines the likelihood of personal consequences that could result from the threat and asks oneself the following: "Do I need to take protective action?" At this point, which is also discussed in human factors research as "situation awareness" [75], the individual tries to gain insight on the potential outcomes of the disaster and what those potential outcomes mean for his safety. The internal dialogue that takes place at this stage can be thought of as mental simulation or mental modeling [56], in which the individual develops a mental model of what is going on in his environment, based on perceived cues, and then expands the mental model to predict the personal consequences of the event. The more certain, severe, and immediate the risk is perceived to be, the more likely the individual is to perform protective actions [76].

In the third and fourth stages, the individual engages in a decision-making process to identify (1) what can be done to achieve protection; and (2) the best available method of achieving this

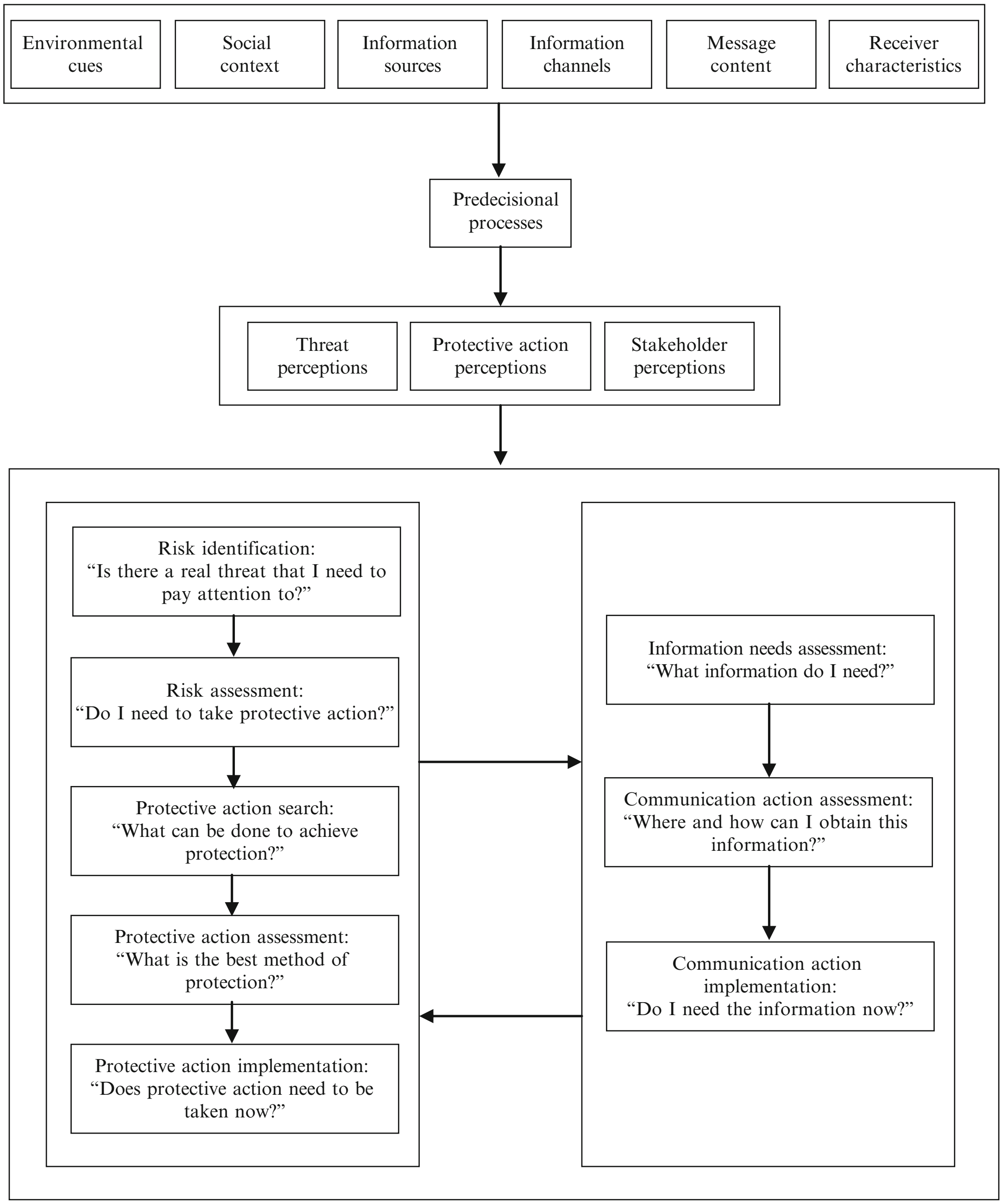


Fig. 58.2 The protective action decision model [73]

protection. The outcome of the third stage is a set of possible protective actions from which to choose. After establishing at least one protective action option, individuals engage in the fourth stage of the PADM: protective action assessment. This stage involves assessment of the potential option(s), evaluating the option(s) in comparison with taking no action and continuing with normal activities, and then selecting the best method of protective action (e.g., evacuating, sheltering in place). Once an action is chosen, the end result of stage 4 is an adaptive plan, which can vary in its specificity. For example, for households under threat conditions,

> [a]t a minimum, a specific evacuation plan includes a destination, a route of travel, and a means of transportation. More detailed plans include a procedure for reuniting families if members are separated, advance contact to confirm that the destination is available, consideration of alternative routes if the primary route is unsafe or too crowded, and alternative methods of transportation is [sic] the primary one is not available [50].

After a protective action is chosen and the adaptive plan is developed, the final step in the decision process involves the implementation of the protective action plan or strategy. Here, the individual asks whether the protective action needs to be taken now. If the answer is yes, then s/he engages in that action. However, Lindell and Perry [50] note and other studies confirm [18, 77, 78] that individuals are still likely to delay the performance of protective action, even when the threat is perceived as imminent.

Passage through these stages is often problematic. If at any stage the individual is uncertain about the answer to a question, s/he engages in additional information-seeking actions. Information seeking is especially likely to occur when individuals think that time is available to gain additional insight on the question at hand. If information seeking is successful, in that the person at risk judges s/he has obtained enough information to answer the question, then the individual moves on to the next stage or question in the decision-making process. However, if the information-seeking action is unsuccessful, there will be additional searching for information as long as s/he is optimistic that other sources or channels can help [50]. If s/he is pessimistic regarding future information seeking success, s/he is likely to attempt to decide on a protective action based solely on whatever information is available.

This description is not meant to imply that decision processes are linear and straightforward. For example, information feedback loops allow for the receipt of new environmental and social cues after initial engagement in information-seeking actions. An individual who gains additional information is likely to carry on with the decision-making process until s/he is ready to implement a protective action. Additionally, individuals do not have to go through each stage or question in the decision flow chart [50]. For example, if an individual is presented with information about the event from a credible source or if s/he is ordered to evacuate, s/he may move on to later stages in the decision process rather than going through each one in succession.

This decision-making framework describes the process of how individuals respond to disasters. Even though the focus of the models discussed so far is on community-wide disasters, it is clear that the models also apply to decision-making during more localized types of events, such as building fires.

Engineering Implications of the Protective Action Decision Model

Engineers must understand that response to fires and other disasters is the result of a process. Individuals or groups of individuals engage in a decision-making process (i.e., a series of steps) before they respond, based upon the cues presented from their environment (including information), the social context, personal characteristics, past experience [23, 76, 79–81] and hazard knowledge [82]. With this understanding, the engineer should recognize that occupants of a building are unlikely to evacuate immediately, and simultaneously, and instead, recognize that occupants are required to receive and process information on an individual- (or -group-) basis. Also important is that if, at any time in the process, the answer to a decision-making question is unclear (See Fig. 58.2), then the individual will engage in information-seeking actions. Information-seeking actions take time to complete and delay the occupant from reaching safety.

Additionally, just because cues or information are provided to building occupants does not necessarily mean that they will act appropriately.

The cues or information must be perceived (e.g., heard or seen), paid attention to, and then comprehended first before any actions take place. Therefore, engineers must ensure that any information meant for building occupants must be provided in such a way to ensure that these three processes take place. One example of this is to ensure that the public address announcements disseminated in a building fire are set to an appropriate volume level such that all occupants in the buildings can hear them; and if not and in order to reach occupants with hearing disabilities, other means of disseminating the information are used (e.g., visual signage) [83].

Engineers should also acknowledge that occupants must perceive a credible threat and personalize the risk before taking action. Research has shown that individuals are more likely to identify and personalize the risk if they perceive a larger number of cues [43, 84, 85] that are intense or extreme in nature [86, 87]. In building fires, for example, occupants who witness heavy, thick, black smoke that decreases visibility and irritates the eyes are more likely than those noting less intense cues to realize that a serious event has taken place that puts them in danger [88]. However, it is always the responsibility of the engineer to protect building occupants, which includes limiting their exposure to fire effluent.

The main way to prompt safe, effective, and appropriate action from building occupants is to disseminate warning messages during fire emergencies that will positively influence risk identification and assessment. Research has shown that a ***successful warning message*** contains the following factors or qualities:

- Specific about the threat and the risk involved [89–91],
- Repetitive [50],
- Consistent [92],
- Disseminated via multiple channels [93],
- Provided by a credible source [49, 76, 81, 94].

Source credibility is defined in terms of the source's expertise, including access to special skills or information, and trustworthiness, or the perceived ability to communicate information about the disaster without bias [50, 54]. Source credibility can differ depending upon a number of factors, including the type of disaster, characteristics of the source, such as social role and believability, and characteristics of the warning receiver, such as past experience in disasters and social location [95–100]. For some warning receivers, credible sources may be friends and relatives, and for others, credible sources may be disaster authorities, such as government officials [101, 102] or fire fighters [38].

As far as content, a warning message should contain five important topics to ensure that building occupants have sufficient information to respond with little or no additional delay and information seeking [38, 103]. These five topics, labeled here as the five W's of any effective warning message, are as follows:

1. Who is providing the message? (i.e., the source of the message, which should be perceived as credible by the building occupants)
2. What should people do? (i.e., what actions occupants should take in response to the emergency and if necessary, how to take these actions)
3. When do people need to act? (i.e., in rapid-onset events, the "when" is likely to be "immediately")
4. Where is the emergency taking place? (i.e., who needs to act and who does not)
5. Why do people need to act? (including a description of the hazard and its dangers/consequences).

Another way to prompt safe, effective, and appropriate action from building occupants is through training. An individual's past experiences in emergencies, specifically the actions that s/he has performed previously, can influence the actions that s/he considers as options during the current emergency [50, 56, 104]. The individual uses memories of the protective actions s/he performed in the past as options for actions to perform in the current emergency. Similarly, an individual's emergency-based training and knowledge, for example, knowledge about evacuation procedures, can influence the options that s/he develops during an emergency [78, 105–108].

Relating Theory to Practice—Protective Actions in Fires

As shown in the earlier section, research has established the theoretical process through which community residents or building occupants make decisions in response to fires and other disasters [50]. However, these theories do not provide sufficient information on the specifics or the *types* of protective actions in which occupants engage and why they engage in these types of actions during fire emergencies.

Research has been performed that identifies the types of actions that people perform during a building fire evacuation, with a focus on the pre-evacuation period. Both summary research [77, 87, 109] and research on specific incidents [1, 3, 18] highlight certain actions in which occupants are likely to engage. These actions, depending upon the situation, can include seeking information, waiting, investigating the incident, alerting others, preparing for evacuation (or deciding not to evacuate), assisting others, fighting the fire, and searching for or rescuing others. One factor that has been used to differentiate one set of actions from another set of actions is the type of building in which the emergency occurs. For example, individuals who are at home (especially at night) may engage in a different set of preparatory actions than individuals who are awake in their offices when the alarm sounds, for example. Therefore, in this section, studies that have been performed on different types of structures will be presented to identify the actions in which individuals most frequently engaged.

U.S. and UK Residential Studies

One of the first studies of behaviors performed during residential fire evacuations was by Wood [15]. The study involved 2193 fire-department conducted interviews with residents from 952 residential fire incidents in Great Britain. Within the same decade, Bryan [14] also studied residential fire incidents by analyzing on-scene interviews conducted by fire service personnel with 584 participants from 335 fire incidents in the United States.

Both researchers found that behavioral responses to fires could be categorized into the following actions: notifying others, searching for the fire, fighting the fire, calling the fire department, getting dressed, getting the family, asking others to call the fire department, gathering personal property, closing the door to the fire area, turning off appliances, doing nothing, attempting to evacuate, and evacuating; among other more specific actions. The most frequent behavioral responses to fire in both the UK and US studies were identified as evacuating the building, fighting or containing the fire, and notifying other individuals or the fire brigade.

Bryan and Wood also organized these actions into first, second, and third actions in an attempt to begin to order the actions taken during the residential evacuation process. In both studies, it was found that investigation actions, such as searching for the fire; notification actions, such as notifying others, pulling the fire alarm or getting family; and preparation actions, such as fighting the fire, turning off appliances, and getting dressed; were performed. In the U.S. study, Bryan [14] indicated that the action of "investigate" was very common as a first action by 45 % of occupants in the sample and as a second action by 23 %. These authors also report that actions such as "mitigate the fire," "help others," and "call for help" were in the middle of the actions sequence, and "escape" or "go for help" were at the end of the usual sequence of four to five actions. "Call the fire brigade" was generally a fourth action, and "fight the fire" usually occurred between the second and sixth actions.

Bryan [14] and Wood [15] also identified actions that were specifically linked to engagement with the fire and/or subsequent toxic products produced by the fire during these residential evacuations. Some percentage of occupants in both studies engaged in fire-fighting behavior, re-entry behavior (i.e., they returned to the structure after leaving), moved some distance through smoke, and/or turned back (i.e., stopped their movement to or into smoke and redirected based on environmental conditions) [77]. These results show that individuals were likely to engage in potentially risky behavior, such as fire-fighting or re-entry behavior, during the fire incident.

For more information on the psychophysical effects of smoke on individual movement and actions, including the visibility distances in which people moved through smoke or turned back, please see Chaps. 61, 63, and 64.

MGM Grand Hotel Fire

Analysis was also performed on the behaviors engaged in during the MGM Grand Hotel fire in Clark County, Nevada, on November 21, 1980 [110]. This hotel fire involved both injuries and fatalities among the guests. The management of the MGM Grand Hotel, and the Clark County Fire Department, in cooperation with the National Fire Protection Association (NFPA) [111], conducted an intensive study of the guests registered in the hotel for the evening of November 20 to 21, 1980, to determine how the occupants became aware of the fire incident and their behavioral responses.

The MGM Grand Hotel fire was discovered by an employee of the hotel who entered the deli-restaurant located on the casino level of the hotel at approximately 7:10 a.m. on November 21, 1980. The fire reached a flashover condition in the deli area, 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 initial fire department personnel. The heat and smoke extended from the casino area through seismic joints, elevator shafts, and stairways throughout the 21 residence floors of the hotel. The heat was intense enough on the 26th (top) floor to activate automatic sprinkler heads located in the lobby area adjacent to the elevator shafts.

Due to the rapid early evacuation of the telephone staff, guests in their rooms were not alerted by the hotel public address system nor the local fire alarm system. Guests who were alerted early in the fire incident, or guests already awake and dressed, were able to escape prior to the smoke conditions becoming untenable on the residential floors. Guests alerted later in the progression of the fire incident remained in their rooms or moved to other rooms, often with other occupants. The flame propagation did not extend above the casino level, with the exception of very minor extension into two guests' rooms on the 5th floor. The fire resulted in 85 fatalities to guests and hotel employees in the following areas of the hotel [110]: 14 persons were found on the casino level, 29 persons were found in guest rooms, 21 persons were found in corridors and lobbies, 9 persons were found in the stairways, and 5 persons were found in elevators. The victims were located on the casino level, and the 16th through 25th floors, with the majority of fatalities found between the 20th and the 25th floors. Various estimates have been provided of the number of guests and fire department personnel that suffered injuries at the MGM Grand Hotel fire. Morris [112] indicated that 619 persons were transported to hospitals from the fire scene, and another 150 guests were treated at the Las Vegas Convention Center, where the survivors had been transported.

Behavioral responses from survivors of this fire were elicited from 554 returned mail-surveys. Similar to the residential studies, one topic of interest was to collect information on the types of behaviors in which survivors engaged. The initial five behavioral responses of the 554 guests as elicited from the NFPA questionnaire study are presented in Table 58.1. The five most frequent first behavioral responses were "dressed," "opened door," "notified roommates," "dressed partially," and "looked out window." The guests involved in the first responses were predominantly engaged in attempting to define and structure the fire cues relative to the severity of the threat to themselves. Only a small percentage, approximately 8 % of the study population, initiated or attempted to initiate their evacuation behavior as the first response.

Examination of Table 58.1 indicates the five most frequent behavioral responses reported by guests as second actions were "opened door,"

Table 58.1 Compilation of the initial five actions of guests in the MGM grand hotel fire incident [111]

Actions	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 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 room	–	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	20.4
Total (percent)	100.0	99.1	96.9	90.4	79.6
Number of guests	554	549	537	501	441

"dressed," "went to exit," "dressed partially," and "secured valuables." Whereas approximately 40 % of the population was engaged in evacuation or sheltering actions by the second act, others were engaged in protective actions. Approximately 19 % of the study population reported they were involved in the dressing actions, 10 % were involved in notification activities, and 7 % were gathering valuables prior to initiating evacuation or seeking refuge.

Examination of the third behavioral responses of the 537 guests in the study population indicated the responses of the guests generally progressed to evacuation, attempted evacuation, and notification responses. Thus, approximately 25 % of the MGM Grand Hotel fire incident study population was involved in evacuation-related behavioral responses, and approximately 10 % of the guests were involved in attempted evacuations as identified by their third responses of "attempted to exit" and "returned to room." The alerting and notification actions of the guests were involved with the third behavioral responses of "notified occupants" and "notified other room."

The fourth behavioral responses of the guests in the study population indicated a progression of the guests to evacuation, attempted evacuation,

Table 58.2 Activities prior to evacuation reported in telephone survey by survivors of WTC 1 and WTC 2 [1]

Activities before evacuation	Percent reporting the activity (n = 440 in WTC 1) (%)	Percent reporting the activity (n = 363 in WTC 2) (%)
Talked to others	70	75
Gathered personal items	46	57
Helped others	30	34
Searched for others	23	32
Talked on telephone	16	16
Moved between floors	8	8
Shut down computers	6	7
Continued working	3	6
Fought fire or smoke	6	1
Other activities	25	20

Source: NIST WTC Telephone Survey Data
Note: Total does not add up to 100 % because respondents may have taken multiple actions

and self-protection or room refuge procedural responses. Additionally, the fifth behavioral responses of the guests were primarily for self-protection, including the improvement of the room as an area of refuge, and evacuation behavior.

Overall, in this hotel fire, hotel guests were more likely to take initial actions investigating, notifying others, and preparing for evacuation, which in this case involved getting dressed. This is similar to the residential studies, likely because a hotel and a residence involve similar living circumstances. In both cases, individuals may be alerted to a fire when they are sleeping—meaning that they will require additional time to prepare for evacuation; i.e., getting dressed themselves or getting other family members dressed. Then, after initial investigation, preparation and warning activities ended, and hotel guests engaged in protective actions and evacuation.

2001 World Trade Center Disaster (Office Buildings)

Different from a residential or hotel fire, studies were performed on the 2001 World Trade Center (WTC) evacuation of the two office towers [1, 22, 30]. On September 11, 2001, two commercial airplanes flew into World Trade Center (WTC) Towers 1 and 2 and initiated full building evacuations from both 110-story office buildings. At 8:46 am, Flight 11 slammed into the north face of WTC 1, disconnecting the entire population above the 91st floor from any way out of the building. It was at this moment that the largest full-scale building evacuation in history began for occupants who had the opportunity to evacuate from both WTC 1 and 2. None of them knew, however, that another commercial jet was on its way—one that was heading straight for WTC 2. Sixteen minutes after WTC 1 was struck and after one-third of WTC occupants had already evacuated,[3] Flight 175 sliced into floors 78 to 84 of WTC 2 leaving only one of the three stairs available for evacuees above the 78th floor. Occupants who could evacuate continued to pour from the structures until the towers eventually succumbed to structural collapse (WTC 2 collapsed at 9:58:59 am and WTC 1 collapsed at 10:28:22 am).

The frequency of actions performed in the 2001 WTC disaster by occupants evacuating Towers 1 and 2 was reported by Averill et al. [1] and Day, Hulse and Galea [113], shown in Tables 58.2, 58.3 and 58.4 below. The focus here is an understanding of the actions taken before evacuation movement in the stairs began. As part of the NIST WTC study [1],

[3] 21 % from WTC 1 and 41 % from WTC 2.

803 interviews were conducted via telephone using a computer program that allowed the interviewers to collect data electronically, also known as computer-assisted telephone interviewing (CATI). Quantitative data was captured via an interview schedule designed to measure the following five primary areas: preparedness and training, initial September 11 experience, interim September 11 experience, evacuation experience on September 11, and respondent demographics. The two populations selected for study were all of the people who worked in WTC Tower 1 and WTC 2 who were in the buildings between 8:46 am and the time at which their respective Tower collapsed on September 11, 2001. In the UK, the WTC evacuation was also studied as part of an in-depth research project carried out by the Project High-rise Evacuation Evaluation Database (HEED) research team [22]. Project HEED was a 3-year project to explore human behavior associated with the evacuation of high-rise buildings. The basis for this project was an analysis of the 2001 WTC disaster through both face-to-face interviews with survivors and computer simulation of the evacuation. The project resulted in over 250 face-to-face or telephone interviews with survivors from the 2001 WTC disaster, collected to both inform the development of future building regulations and evacuation computer models and to make data available to bona fide building safety researchers in countries around the world. In both cases, the studies' presentation of actions taken was not ordered in any way (i.e., first, second, and third actions); however, both studies provide an understanding of the actions that were most frequently performed from one tower to another.

Averill et al. [1] presented a list of the "general" pre-evacuation actions performed in both towers, shown in Table 58.2, below, acknowledging that not all actions were covered by these categories by including the "other" category at the end of the list. The majority of individuals in both towers engaged in actions that involved talking to others (70 % in WTC 1 and 75 % in WTC 2) and gathering personal items (46 % in WTC 1 and 57 % in WTC 2). Additionally, about a third of occupants in both towers engaged in helping others and searching for others.

Day, Hulse and Galea [113], on the other hand, grouped pre-evacuation actions into two different categories: information tasks and actions tasks (shown in Tables 58.3 and 58.4). Information tasks, which involved action taken to obtain or receive information, were further divided into three different areas: seeking

Table 58.3 Comparisons of information tasks by tower [113]

	WTC1		WTC2	
Information tasks	% PPTs	Freq	% PPTs	Freq
Seek information tasks				
Environmental (e.g., window)	53	66	83	142
WTC colleagues/friends	36	44	27	46
Waited for further info	13	17	8	11
People outside WTC (e.g., called family, friends)	8	17	3	4
TV/internet/radio	2	2	6	7
Professional bodies (e.g., port authority, security, police, fire)	2	2	5	6
Communication tasks				
Instruct others to evacuate	34	51	40	89
Inform others of my situation	17	25	30	63
Debate/challenge	3	5	11	15
Receive information tasks				
Non-professionals (e.g., managers, family)	12	16	23	35
Professionals (e.g., PA announcements, security, police, fire)	8	9	19	31

WTC1: N = 119, WTC2: N = 121, PPTs participants

Table 58.4 Comparisons of action tasks by tower [113]

Action tasks	WTC1 % PPTs	WTC1 Freq	WTC2 % PPTs	WTC2 Freq
Personal tasks				
Collected personal items (e.g., wallet)	60	141	63	145
Went to toilet/comfort break	3	3	2	2
Changed footwear/glasses	3	3	1	1
Emergency tasks				
Evacuation facilitation (e.g., searched office/floor, forced exit open)	19	25	26	47
Waited for others so evacuate together	7	8	14	17
Gave others physical assistance (e.g., carried/gave first aid)	6	7	3	4
Protective action (e.g., took refuge, blocked/sealed cracks, got under smoke, made masks)	7	8	3	4
Distributed useful items (e.g., mobiles, masks, bottled water)	0	0	1	1
Work tasks				
Secured items/areas (e.g., locked files, bank vaults)	7	10	3	4
Tidied desk	3	5	8	14
Latent tasks				
Denial/Froze/continued working	2	2	13	17
Travelled to another area/floor/stairwell (reason unknown)	4	5	3	4

WTC1: N = 119, WTC2: N = 121, PPTs participants

information, communicating with others, and receiving information. The action tasks, a term which was not specifically described by the authors, was subdivided into additional categories: personal, emergency, work and latent actions. According to this study, and similar to Averill et al. [1], the majority of tasks undertaken by the participants were "Information tasks" (54 % in WTC 1 and 63 % in WTC 2)—specifically the action termed as "seeking information". Additionally, the most common "Action Tasks" performed by occupants in each tower were "Personal Tasks"—accounting for 68 % of the "Action Tasks" in WTC 1 and 57 % in WTC 2. Personal tasks involved occupants collecting or packing up their personal possessions before evacuating the building. Day, Hulse and Galea [113] also tracked the number of tasks completed by each participant in the study. The range of tasks completed was between 0 and 13 in WTC 1 and 2 and 21 in WTC 2; with an average number of tasks completed in WTC 1 of 3.96 and an average number of tasks completed in WTC 2 of 5.86.

Table 58.5 Range of times associated with WTC pre-evacuation actions [30]

Action	Range of timing (minutes)
Preparation (Action task, personal)	0.5–5
Communicating with others (Information task)	3
Looking out the window (Information task)	1–5
Helping, by authorities (Action task, emergency)	4–10

While most empirical studies of actual incidents [114–116] and evacuation drills [117–119] provide overall timing estimates for activities in the pre-evacuation period, very few researchers discuss times associated with specific pre-evacuation actions. From analysis performed by this author on the Project HEED database [30], pre-evacuation action times were reported by some WTC occupants and are presented in Table 58.5 as a range of times (minutes) for each action type.

University Library Building in the Czech Republic

From a study of an unannounced evacuation drill in a university library in the Czech Republic, Galea et al. [120] collected data on the number, type and duration of pre-evacuation actions. To begin the evacuation, the alarm system, consisting of a combination of tones, recorded voice and live voice messages, was activated. The recorded voice message began by stating the word "attention" multiple times, followed by a declaration that an emergency situation was taking place. The message also instructed people to prepare for evacuation and wait for further instruction. Two live messages were also disseminated during the drill. The message made it clear that the evacuation instruction was directed at occupants in the library building only and then gave instructions on the routes to take, depending upon where the individual was located within the library building. The live messages also warned individuals not to use the elevators, and to only use the stairs to evacuate. On the day of the trial, the alarm system failed to operate in certain parts of the library building. Some individuals heard the alarm tone and announcements and some did not. In the places where the alarm failed to function, the evacuation was initiated by staff intervention.

Video observation and analysis of the evacuation drill allowed for the collection of pre-evacuation action (or task) type and duration. In this study, similar to the WTC study presented above, pre-evacuation actions were categorized in two different ways: information tasks (or actions that involve the occupant seeking, providing or exchanging information regarding the incident) and action tasks (or all other types of pre-evacuation actions, e.g., preparation, fighting the fire, helping others, etc.). Throughout the evacuation, 235 information tasks and 268 action tasks were completed; the average number of information tasks (per person) was 3.7 and the average number of action tasks (per person) was 4.3. On average, an evacuee in this study engaged in a total of 8.0 tasks prior to beginning evacuation movement (e.g., into the stairs).

There were differences in task numbers between evacuees who received staff intervention and those who were alerted by the alarm system. For those who were alerted via staff intervention, the average number of information tasks was 2.0 and the average number of action tasks was 3.6; for an average number of total tasks performed prior to beginning evacuation movement of 5.6. For those alerted via the alarm system, the average number of information tasks was 7.4 and the average number of action tasks was 5.7; for an average number of total tasks of 13.1. The authors of this study noted that individuals alerted by the alarm engaged in twice as many tasks during pre-evacuation than individuals notified by a member of staff.

Work was also performed to measure the time to undertake each individual task from the video footage [120]. The analysis showed that the average duration of a single action task was 6.4 s and the average duration of an information task was 9.7 s (independent of how an evacuee was alerted to the incident). The authors concluded that, in this study, an information task took 1.5 times as long as an action task. Analysis of task timing was also performed by comparing the two groups alerted to the drill via different means. For the population alerted by staff intervention, the average time for an action task was 6.5 s and for an information task was 6.7 s. On the other hand, for the population alerted by the alarm system, the average time for an action task was 6.4 s and for an information task was 9.9 s. The authors of this research noted that there was a considerable difference in the average time to complete information tasks among the two populations—showing that the population alerted by the alarm system took a longer time (on average) to complete information tasks in comparison to the population alerted by staff intervention. This highlights the greater influence of in-person, official communication/instruction on a faster response time when compared with an alarm system.

University of Greenwich Dreadnought Building (Educational and Library Services Building)

A study was performed on an evacuation of a university building known as the Dreadnought building, located on the University of Greenwich campus in London, UK [121]. The Dreadnought building is a three-story structure used for a variety of purposes, including library services, student computing facilities, and a small cafeteria. Data were collected by research staff located at 15 key locations throughout the building via handheld video and manual observations. Additionally, questionnaires were handed out to all evacuees to collect information about their experience during evacuation. Last, 62 closed-circuit cameras were used to gather data on the starting locations of evacuees, their behaviors/actions, and response times. Because of camera locations, initial responses and times could only be captured for 247 evacuees of this building: 228 students and 19 members of staff. In this building, once the alarm sounded, nominated members of staff swept each room, "forcing students to leave their work and belongings, and informing them of the routes they should adopt" [121].

During analysis, a dictionary of potential actions was created based upon examination of the video evidence from the evacuation. The list of actions comprised of the following:

- Evacuate immediately
- Perform a computer shutdown
- Disengage socially
- Collect items, including bags, coats, paperwork, etc.
- Investigate the incident.

Additionally, it was found that 27 % of the participants of this study completed one or no actions prior to beginning evacuation, 55 % completed two actions, and 18 % completed three or more.

Engineering Implications of Actions Taken During Evacuation

Engineers should understand that actions, both information-related actions and protective actions, are performed during fire evacuation. Depending upon the circumstances, these actions can take a considerably long time to complete and will contribute to the time to reach safety. First, engineers must account for these actions in some way when calculating evacuation timing in a proposed design building fire. Actions and delay times associated with these actions can be especially important in certain types of buildings, where individuals are likely to engage in certain types of lengthy actions; i.e., those in which people may be asleep or located on upper floors of uniquely tall buildings. Many times, when performing an evacuation calculation, engineers are asked to provide a specific pre-evacuation time period or distribution as input. Engineers should choose a time that is based upon specific scenarios and resulting occupant actions (and action timing). Additionally, to improve occupant response, engineers should account for evacuation actions when developing fire evacuation plans for buildings. As stated earlier, research has shown that providing specific warning information in certain ways or providing leadership to prompt evacuation response could reduce the need for information seeking, and even the performance of certain protective actions. If engineers understand which evacuation actions they should anticipate in a specific building or fire scenario, they can formulate plans that are successful in decreasing delays caused by evacuation actions. Therefore, it is important to first understand that types of actions that individuals have engaged in previous fires and how these actions can vary from building to building, and from fire event to fire event.

Relating Theory to Practice—The Sequence of Protective Actions in Fires

Beyond identifying the types and percentages of actions, including the percentage of actions that were performed first, second, and third, research has been performed to identify the sequence of actions taken in different types of fires. Canter, Breaux, and Sime [78] developed decomposition diagrams for various types of fire events that identify the sequence of actions. The study was conducted in the United Kingdom on domestic fires (14 domestic fires and the acts of 41 persons), multiple-occupancy fires (eight multiple-occupancy fires and the acts of 96 persons), and hospital fires (6 hospital fires and the acts of 61 persons). All persons in this study were interviewed about their experiences in the fire; first asking them to give a detailed account of everything that happened starting from the time at which they considered that something out of the ordinary might be occurring. Once individuals had given full accounts, interviewers questioned respondents on certain issues, including recognition of the fire event, location of the occupant, ongoing behavior, sequence of actions, perception of the situation, past experiences, and background information.

The results of this analysis were the development of decomposition diagrams. These diagrams are provided here, as Figures 58.3, 58.4, and 58.5. Dashed circles indicate the acts which occurred with a lower frequency. The relationships between acts are indicated by arrows; and if actions are repeated, the circle (representing the action) would have a looped arrow coming back on itself. The numbers next to an arrow refer to the strength of the association. The higher the association number, the greater the association is; i.e., the more likely it is that given the performance of one act, the next action (specified) will follow.

The decomposition diagram for domestic fires is shown in Fig. 58.3. The domestic diagram summarizes 1189 acts which occurred in 14 domestic fires. It outlines departure from pre-event activities, such as sleeping, to a range of other investigative, notification, and preparation activities. In these domestic fires, individuals tended to perform actions related to investigating which involved encountering or engaging with the fire in some way, and then evacuating; or discuss the situation, notify or warn others, preparing to evacuate, and then leaving the house.

The decomposition diagram for multiple occupancy fires is shown in Fig. 58.4. The multiple occupancy diagram summarizes 1714 acts which occurred in all eight multiple-occupancy fires [78]. All fires occurred in the United Kingdom in hotel occupancies. Similar to the domestic fires, occupants went to investigate the receipt of strange noises, which led to them encountering the fire environment and/or warnings about the emergency. If direct contact with the fire environment ensued, the characteristic sequence that followed involved the occupant going to the window, shouting for help, and then being rescued. Also similar to domestic fires, occupants engaged in activities such as warning others, gathering personal items, and closing or opening windows.

The decomposition diagram for hospital fires is shown in Fig. 58.5. The hospital diagram summarizes 1104 acts which occurred in all six multiple-occupancy fires [78]. The case studies covered a variety of hospital types, i.e., geriatric, psychiatric and general medicine; however, patterns were still revealed among the entire population, as a whole. Detection and investigation actions are performed relatively early in these fires, possibly because the higher spread of people in the building. Also, the sequence of actions is different in this diagram, when compared with others, due to the nature of the organizational hierarchy of the hospital. Senior nursing staff, whose job it was to investigate the fire, relay information to junior colleagues, who then had a series of actions that they performed in response.

The reader should note the inclusion of process-related factors (first described in the PADM) into these action-based diagrams. For example, Figures 58.3, 58.4, and 58.5 contain circles for the receipt of cues, i.e., "hear strange noises" or "encounter difficulties in smoke", which are not actions. Instead, these are processes in which individuals engage in order to act in a building fire. Also, all three diagrams contains circles for the interpretation of cues, i.e., "misinterpret (ignore)". The domestic diagram even contains an entry for "feel concern". These entries also are not actions, but interpretations about the situation and personal risk (first described in the PADM) as direct

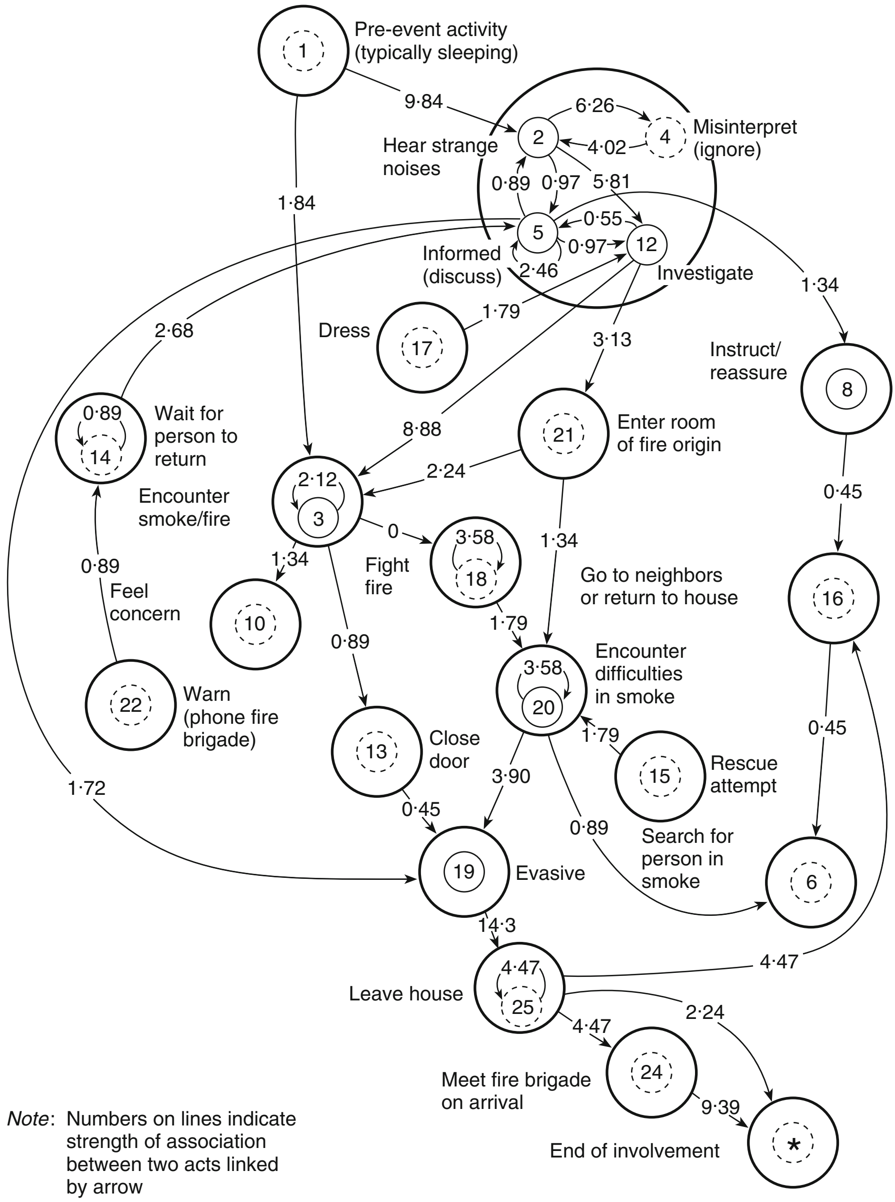


Fig. 58.3 Decomposition diagram—domestic fires [78]

influences of actions. These diagrams truly represent the first attempt at developing an inclusive conceptual model of evacuation actions—that identify not only the action, but also the processes of receiving cues and processing information in order to act in an emergency.

Patterns of behavior exist across all three diagrams (of varying occupancy type). What is important to note here is that certain actions take place in specific locations within the evacuation sequence. First, immediately after the receipt of initial cues, individuals were more likely to

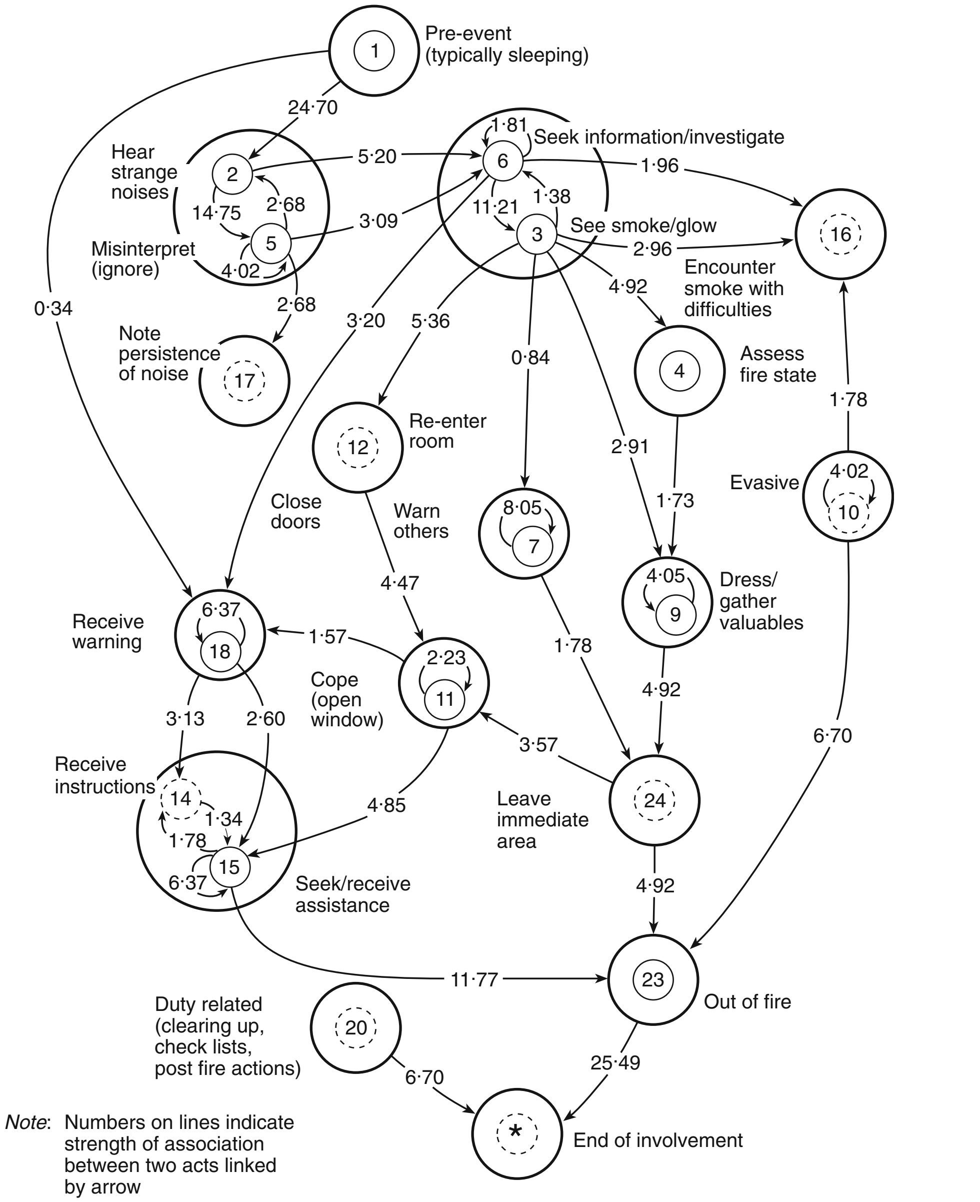


Fig. 58.4 Decomposition diagram—multiple-occupancy fires [78]

'investigate' the situation and/or 'misinterpret' (or ignore) cues that they received early on in the event. Then, after seeing smoke, one of three 'prepare' sequences were more likely to be performed, including 'instruct', 'explore', or 'withdraw'. Finally, depending upon the particular preparation action chosen, occupants were more likely to engage in the following actions: 'wait', 'warn', 'fight' or 'evacuate'.

Engineering Implications of the Linkage of Actions Taken During Evacuation

Actions follow a specific pattern across all types of building fires, and an understanding of the patterns of behavior is important when attempting to accurately model an evacuation scenario (i.e., the methods outlined in Chap. 57). Take for example, an office building

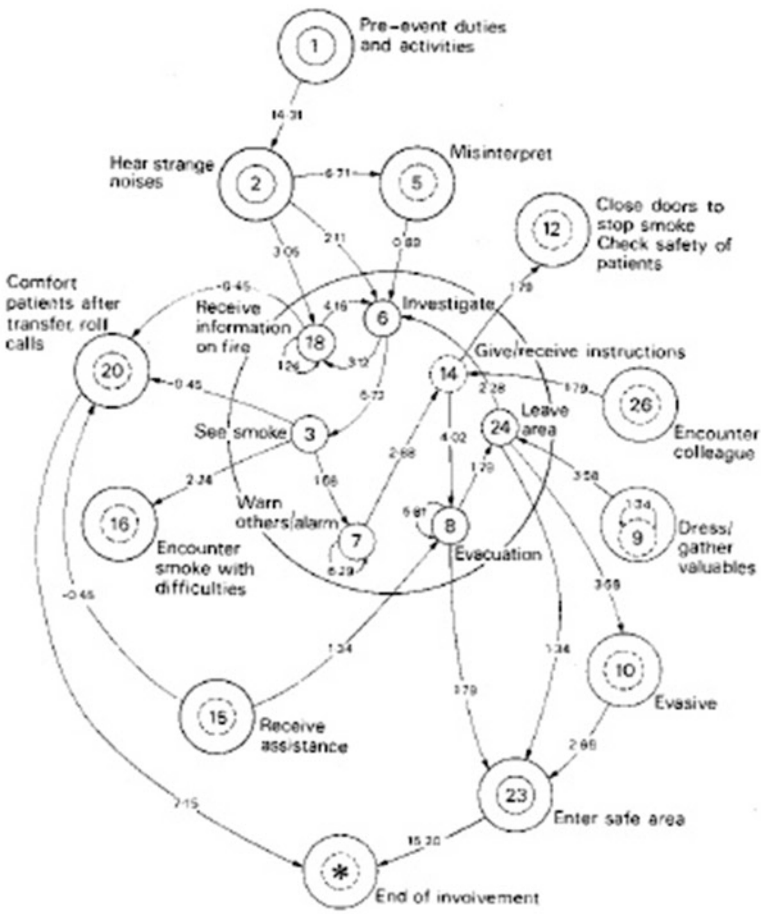


Fig. 58.5 Decomposition diagram—hospital fires [78]

that houses a child daycare for its employees on the 10th floor of a 20-story building. It will be important for engineers to understand that occupants will spend some period of time on their floors investigating the situation and making decisions as to what needs to be done; i.e., if evacuation is necessary or not. Therefore, a determination of the fire and smoke conditions on any occupied floor is important immediately after the fire begins. Next, the engineer should understand that some proportion of occupants may travel to the 10th floor to rescue their children from the daycare center, requiring an assessment of the environmental conditions on that floor for some time period after investigation is complete (i.e., the protective action phase).

An understanding of the behavioral process is important also for the design of evacuation procedures for a building. For example, the presence of staff as well as a building alarm for alerting the population of a building fire may decrease time spent investigating and deciding to evacuate. If staff members instruct building occupants to evacuate, especially if they represent a credible source to the population, then building occupants may be more likely to begin evacuation sooner than if left to their own decisions [30].

Relating Theory to Practice—Group Behavior

Research also exists to explain observations from numerous fire studies that people tend to travel or converge into groups during emergencies. There are theories that support the idea that individuals come together and form a group before evacuating, and then continue their evacuation together until they reach safety. This behavior, labeled as affiliative behavior [107], is described first in this section. Individuals also come together in groups to help one another. Helping behavior is found in almost every disaster, and an overview of this behavior will also be provided in this section. Finally, individuals have been found to converge together in groups during emergencies in order to take refuge from the fire conditions. Convergence groups, or clusters as termed by Bryan [77], were found in situations whereby individuals attempted evacuation and decided that is was not possible at the time.

Affiliative Behavior

According to Sime, who developed the Affiliative model, there is a relationship between people and their physical settings [107]. This model assumes that individuals with close psychological ties will attempt to escape with other group members during an emergency evacuation. Through his study of the Summerland fire, he found that nucleus family members were more likely than others to maintain group ties during travel to and through exits. Mixed groups, on the other hand, including friends and/or relations, did appear to have been less concerned with maintaining group ties during evacuation than they might have under normal circumstances.

Proulx also found this trend in group behavior while studying evacuation timing in apartment building evacuations [122]. Through the analysis of video tapes, it became apparent that people traveled in groups during evacuation: families with children would typically evacuate in a close group with an adult carrying the smallest child. However, family groups would split slightly when traveling with children who were a bit older in age. Additionally, seniors also traveled in groups of two or three; noting that they would exit their apartment and gather to discuss the drill, finally proceeding to evacuate together. Overall, Proulx found that 62 % of the occupants (in the four buildings studied) evacuated in groups. One important aspect to note is that Proulx also monitored the speed of movement of building occupants and found that groups tended to assume the speed of the slowest person, which in many cases in the apartment buildings studied were young children or older adults. Also, people tended to stop to converse during evacuation, rather than maintain the same speed throughout the entire evacuation.

Helping Others

Occupants also help one another during building emergencies, bringing people together in groups at one time or another. Analysis of building fires [77, 78, 108] and community-wide disasters, such as tornadoes [123, 124] and hurricanes [125, 126], provide many examples of instances where evacuees are often the first responders in any emergency. For example, Johnson, Feinberg and Johnston's study [127] of the Beverly Hills Supper club event (where a fire broke out in a nightclub in Kentucky in 1977, causing 165 deaths and over 200 injuries) showed that people put themselves in what they categorized as "grave danger" while assisting others in their group—"at times, returning to the burning building to search for loved ones; staff performing heroic acts while trying to save their clients". Aguirre et al. [128] through their study of another nightclub fire (i.e., The Station Nightclub Fire), which occurred at approximately 11:09 p.m., on February 20, 2003, in West Warwick, Rhode Island [129], found evidence that people cooperated and took care of one another in their group during and after the evacuation, which was a key aspect of their survival.

Drury, Cocking, and Reicher [32] discuss the reasons why helping behavior occurs in emergencies. They claim that people help others in moments of crisis not only because they know and care about each other, but also because individuals have "internal cognitive categories" that allow identifications with others in certain contexts. In other words, an emergency requires individuals to redefine the situation collectively (as discussed in an earlier section of this chapter), and through this redefinition, individuals can form a sense of 'we-ness'. In emergencies, the redefinition of most situations, especially building fires, can be one where the evacuees are 'all in this together' or 'all in the same boat'—i.e., in need of protection or in search of survival. This redefinition of 'we-ness' then lends itself to the associated behavior of helping others.

Convergence Clusters (for Refuge)

The phenomenon of occupant convergence cluster formation in a fire incident was initially noticed in a study of occupant behavior in a 1979 high-rise apartment building fire [130]. Convergence clusters appear to involve the convergence of the occupants of the building in specific rooms selected as being areas of refuge, when evacuation was perceived as not possible. In the MGM Grand Hotel fire, for example, guests tended to select rooms on the north side of the east and west wings, and rooms on the east side of the south wing, due to the prevailing atmospheric conditions and the external smoke migration. In addition, guests reported that people had converged in rooms that had balconies and doors leading to the balconies because of the ease of ventilation, the reduced smoke exposure, improved visibility, and the communication advantages the balconies offered. The guests who reported their participation in convergence behavior in rooms provided either numerical estimates of the persons occupying the room or suite, or indicated only that "others" or "other persons" were present. Bryan also recorded the numbers of individuals in each convergence cluster, noting that the smallest number of people identified as a single cluster involved three persons and the largest was 35 persons.

Convergence clusters may serve as an anxiety and tension-reducing mechanism for individuals confronted with a fire incident perceived as life threatening. In addition to the detailed human behavior study of the MGM Grand Hotel fire [131], the NFPA conducted a similar questionnaire study of the guests' behavior in the Westchase Hilton Hotel fire [132] and also found the presence of convergence clusters.

Implications of Describing Behavior in Terms of the Group

The main reason for understanding group behavior, especially these three examples provided above, is because groups take time to form and move together as a unit, with decisions made according to the attributes of the group and movement speeds converging to the slowest member of the group to ensure group cohesion. People have been found to delay their own safety in order to help others. Depending upon where others are located in the building, these actions can take a significant amount of time, delaying movement to safety.

However, the previous sections on actions taken during an evacuation, action sequences, or a description of group processes do not yet tell the entire story of human behavior in fire. Not included are the *causes* of the decisions made and actions performed during fires. The studies of convergence clusters did begin to show that individuals reduce stress and anxiety in emergencies when they meet with members of their social circles; more insight is needed here. Therefore, the following section focuses specifically on the factors that affect decisions made or actions taken during a fire evacuation.

Factors that Influence Behavior in Fire

People in fires very rarely act in similar manners throughout the fire event. Instead, based on various environmental and individual factors, they internalize and process the information, and then act in kind.

Research into community disasters and building fires identifies individual and process-related factors that influence behavior [133]. There are some research that identifies the factors that influence various stages of the emergency decision-making process and others that identify factors that they claim directly influences behavior (however, it is more likely that these factors influence some stage in the decision-making process, that then influences behavior). These factors include social influence (or the influence of others in the building), stress, the built environment, leadership, and demographics (notably gender). Each factor will be described in further detail below and supported by appropriate research studies. It is important to identify these factors so that engineers can identify circumstances within fire scenarios in which certain types of behaviors (resulting in times delays) are likely to occur.

Factor 1: The Influence of Other Occupants on Behavior (Social Influence)

Research has been performed on the influence of others in the building on an individual's response to fire cues. This phenomenon is labeled here as social influence. This section will begin by describing psychological experiments performed by Latane and Darley [52] to test the influence of others on behaviors. Then, the section will describe research findings on the effect of groups (i.e., others who have formed a group tie) on the timing of actions during evacuation.

Latane and Darley [52] created an experimental situation involving college students. While the students were completing a written questionnaire, the experimenters would introduce smoke into the room through a small vent in the wall. If the subject left the room and reported the smoke, the experiment was terminated. If the subject had not reported the presence of the smoke within a 6-min interval from the time the smoke was first noticed, the experiment was considered completed. In some cases, subjects were alone in the room. In other cases, subjects were accompanied by "actors" that were told to remain in the room for as long as the subject did, no matter what. Finally, there were cases where subjects were accompanied by other subjects (or participants) who were unaware of the purpose of the experiment.

Subjects alone in the room reported the smoke in 75 % of the cases. When two "actors" were introduced in the room with each subject, only 10 % of the groups reported the smoke. When the total experimental group consisted of three unknowing subjects, one of the individuals reported the smoke in only 38 % of the groups. Of the 24 persons involved in the eight unknowing subject groups, only 1 person reported the smoke within the first 4 min of the experiment. In the situations involving subjects alone in a room, 55% of the subjects had reported the smoke within 2 min and 75 % reported smoke in 4 min.

Latane and Darley reported that noticing the smoke was apparently delayed by the presence of other persons, with the median delay of 5 s for single subjects and 20 s for both of the group conditions. These results would appear to indicate the inhibiting influences that may be imposed on individuals in public places. Latane and Darley reported the behavioral response of nine of the unknowing subjects in the ten passive research situations as follows [52]:

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

Latane and Darley suggest that, while trying to interpret ambiguous threat cues as to whether a situation requires a unique response, the individual is influenced by the behavioral response of others who are exposed to identical cues. If these other individuals remain passive and appear to interpret the situation as a nonemergency, this inhibiting social influence may reinforce this nonemergency interpretation for an individual. This behavioral experiment may help explain the reported tendency of persons (1) to disregard initial ambiguous fire incident cues or (2) to interpret the cues as a nonemergency condition when the fire incident occurs with a social audience of other persons, as in a restaurant, theater, or department store. This experimental study may also be helpful in understanding the incidents reported to fire departments that have been delayed by occupants for periods of minutes or even hours. In the report of the Arundel Park fire [32], several of the residents indicated that when they re-entered the hall after observing the fire from outside the building, they warned other residents and suggested they leave, but they were laughed at and the warning was disregarded.

Latane and Darley indicated that social inhibition, diffusion of responsibility, and mimicking appear to be primarily responsible for the inhibition of adaptive and assistance behavior responses by participants in emergency situations. It would appear that the inhibition of behavioral responses in the early stages of a fire incident (when the fire incident cues are relatively ambiguous) may predispose participants to a nonadaptive type of flight behavior, since the available evacuation time has been expended. In some fire incidents it appears to be difficult to get occupants of a building to evacuate because of the variables of social inhibition and diffused responsibility. The tendency to mimic the interpretation of cues and the behavior responses of others (as established by Latane and Darley) appears to be a frequent occurrence in fire incidents in restaurants, hotels, and other places of public assembly.

Similar to the studies that showed occupants were less likely to react if others were not reacting, studies have found that individuals are likely to follow others (i.e., begin their evacuation) if they witness others acting/reacting in emergencies. Occupants in the 2001 WTC disaster were likely to begin evacuation if they saw others evacuating as well, and this was especially the case if they viewed this individual (or individuals) as a credible decision-maker [30]. Even more interesting is the choice between stairs and elevators in WTC 2. As discussed earlier in this chapter, there were 16 min between the time that WTC 1 was hit and when WTC 2 was subsequently struck by the second plane. Therefore, occupants of WTC 2 who decided to evacuate before their own building was hit had access to both stairs and elevators. There were individuals in WTC 2 who decided to use the elevators for evacuation. One of the factors that influenced their decision was the presence of other individuals also using elevators for evacuation that day. In addition, similar to elevators, a stair route was not considered an option if no one was using it or if people encountered barriers, such as toxic conditions, that inhibited use.

Research has also been performed on the effect of groups on evacuation timing, or the timing to initiate evacuation behavior. First, Aguirre, Wenger and Vigo [40] performed a quantitative study of the 1993 bombing of the World Trade Center Tower 1 (the north tower). After the bombing occurred, researchers sent 690 mail surveys to management representatives to distribute to the 776 occupants selected using a stratified random sampling technique. Overall, the total sample included 415 respondents (161 from WTC 1 and 254 from WTC 2), for an overall response rate of 53.4 %. In this analysis, the dependent variable was the length of time (in minutes) that respondents took to join the evacuation, with the independent variables of interest being group size (large group of 20 or more people [1] or not [0]) and social interaction (a scale starting with: the respondent did not know anyone in group [0] and ending with the respondent knew everyone very well [11]). Results of this analysis showed that the more people whom respondents knew in their evacuating group, and the better that they knew each one, the longer it took them to initiate their evacuation. Further, respondents in large groups took 6.7 min longer to initiate their evacuation than others. Also of interest was the influence of perceived risk on time to evacuate. The study showed that people who perceived more danger tended to initiate evacuation earlier; however, the opposite was true if they were people in large groups who knew people more thoroughly. In other words, people who perceived risk, but were in larger groups of people whom they knew well, took longer to initiate evacuation. According to the researchers, this finding is likely due to the importance of interacting within the group pro-socially; i.e., spending time trying to help friends or known others to decide to evacuate or prepare themselves before beginning evacuation movement.

Much of the focus of this chapter has been on the behavioral actions taken during evacuation, since other chapters in the handbook focus primarily on movement (e.g., Chap. 59). However, research on social influence has also found that group formation can delay the speed at which the group moves throughout the building during an emergency [122]. This finding is a direct result of the members of the group moving at the speed of the slowest member, so as to keep together during the emergency. Other movement aspects of an evacuation are outside of the scope of this chapter and more information on these can be found in Chap. 59.

Engineering Implications of Social Influence on Behavior

It is important to understand the effects of others on evacuees, especially in highly occupied buildings. In many buildings, occupants are surrounded by others, some of whom they find credible and others they may not. Social influence is especially important to remember when using current evacuation modeling or simulation tools to assess life safety of a structure. Many times, evacuation models simulate each individual (or agent) as if they are not behaviorally influenced by anyone else around them. For example, some models will randomly distribute pre-evacuation times throughout the simulated population, and, when one simulated agent in a room leaves, all other agents remain in place until their assigned pre-evacuation time has expired. This example does not represent a realistic scenario and engineers should be aware of social influence when running simulation tools.

Additionally, a proper understanding of social influence can aid engineers in developing new and more effective evacuation procedures. For example, if a building manager or engineer is aware that designated fire wardens are more likely than anyone else in the building to respond quickly during a fire evacuation, one potential evacuation scenario might be to strategically place these "quick responders" throughout the building (rather than all in one place) to promote faster response from other building occupants. This is simply one example of many for how an understanding of social influence can also help improve occupant response through smarter emergency procedure development.

Factor 2: The Influence of Stress on Behavior (Perception)

Research has also been performed to understand the effect of stress on emergency or evacuation behavior. Stress can be brought on in an emergency via several different complex conditions or states. Other than the obvious threat from physical harm due to the fire, fires can cause other conditions or states, including uncertainty/ambiguity, information overload, and time pressure. *Uncertainty* for building occupants [56, 134] can occur due to missing information, unreliable information (actual or perceived), ambiguous or conflicting information (more than one way to interpret the information) [87, 135], and/or overly complex information. *Information overload* occurs when the individual or group perceives that there is too much information to filter though in the time available, and it is posited that time pressure is necessary to produce the perception of information overload [136]. Last, with *time pressure*, occupants may perceive their situation as urgent and that they only have a limited amount of time to perform certain actions [137]. All of these conditions mentioned above can be considered as stressors for the building occupant [56, 134, 138, 139], leading the occupant to experience a physical state of stress and/or anxiety. In order for the individual to experience acute stress, some of the stressors must be present and the individual must be aware of the presence of stress, motivated to resolve the situation and uncertain of the outcome [138].

One of the main ways in which stress affects evacuation decision-making is through the narrowing of an individual's perceptive field. In this instance, stress makes it more difficult to perceive cues from the event [56, 137], and in turn, individuals may only pay attention to a select number of cues from their physical environment. Because of this, they could very well miss important pieces of information about the event which they would need to make safer or more effective decisions. Additionally, the ability to process information is skewed in three major ways under stress [140]:

- They process information at a faster rate, without carefully connecting the appropriate pieces of information together into an coherent story
- They can engage in the avoidance of optimal decision-making, i.e., making random choices
- Subjectively, the important data are chosen for consideration in the decisions

Another effect of stress on behavior and decision-making is that individuals are more likely to make choices that are less risky, thus, for example, providing additional support for the use of more familiar exits rather than unknown exits during evacuation [66].

Engineering Implications of Stress on Behavior

It is important for engineers to understand the implications of stress because this understanding can help improve the way we design buildings as well as emergency communications systems for fire safety. If individuals are more likely, in stressful situations, to pay attention to a lower number of cues, for example, engineers should design more noticeable signage or warning cues that easily grab people's attention. One example of this is providing information via luminous materials, like visual signage, that are central to people's perception field. Signage should be designed to capture people's attention and keep their attention during a building fire in as many ways as they can (see Kuligowski and Omori [83] for further information on better communication of emergency information during building emergencies).

Factor 3: The Influence of the Built Environment on Behavior

Research has also been performed on the influence of the built environment, i.e., the building, on evacuation behavior. Much of this work has been performed by Jonathan Sime, and refers back to the Affiliative Model [107] presented in an earlier section of this chapter. Similar to how individuals are likely to move toward individuals who are familiar to them before (or during) evacuation movement, people will attempt to use (or evacuate by) the exits or exits routes that are most familiar to them [107]. In general, in the Summerland fire that took place on the Isle of Man in Great Britain in 1973, Sime found that people attempted to leave via the exit route with which they were familiar; often, that was the exit that they had used to gain entry into the building. The Affiliative model also predicts that because a fire route (or exit) is not in regular use, and thus likely unfamiliar to the population, it is less likely to be used in a fire evacuation. People will prefer to use the most familiar exits, and this is exacerbated in emergencies [107].

Nilsson, building upon Sime's findings on familiarity, performed several studies on the features of exits that could increase the attractiveness of one exit over another [141]. He based his analysis of exit design on the theory of affordances [142], which states that people perceive objects in terms of what they can offer or afford. Based upon Gibson's work, Hartson [143] introduces four types of affordances and the types of activities they support:

- Sensory affordance—sensing or seeing
- Cognitive affordance—understanding
- Physical affordance—physically activity (doing or using)
- Functional affordance—fulfillment of an individual's goals

Nilsson [141] provides examples of how the theory of affordances can be used to analyze the design of an emergency exit. The first, or sensory affordance, suggests that the exit must be designed such that it is easy to sense. Nilsson provides specific examples of how to increase an exit's sensory affordance in the following ways: clearly distinguish the door from other elements in the space (e.g., by using color or pattern) and equipping them with flashing lights, as long as sufficient contrast is provided by the environment. Cognitive affordance suggests that people understand that the exit should be used in emergencies and that it can lead them to a safer place. Examples of increasing cognitive affordance include providing an emergency exit sign above the door, placing flashing lights next to the exit sign (which would cover both sensory and cognitive affordances), and providing green flashing lights that is associative with safety or emergency exits (especially in countries where the exit signs are green). Physical affordance suggests that the user should be easily able to open and operate the door in an emergency. An example of increasing physical affordance is providing a door that is easy to open (i.e., no large force is required to open the door). Finally functional affordance suggests that the exit aids the user in obtaining their goal—to escape as quickly as possible. The difficulty, according to Nilsson, with functional affordance is that individuals during a building evacuation may have a multitude of goals; i.e., to not be the only one using an exit (for fear of looking foolish) or to avoid unpleasant environments in the building. Therefore, it is difficult to identify specific examples of increasing functional affordance in a building evacuation.

Finally, studies have shown that the individual's definition (or perception) of their environment can influence behavior during a fire evacuation. Donald and Canter's study of the King's Cross Disaster [144], where a fire began in the escalators of London, UK's King's Cross underground metro station, showed instances of the influence of place. Individuals located in the underground station were told by police officials to evacuate the underground station; however, the location to which they actually traveled depended upon their definition of the underground station. Some were unsure whether "the station" included the ticket hall area or the concourse or both, causing confusion about where they should actually travel to reach a safer location.

Engineering Implications of the Built Environment on Behavior

In all three studies, individuals' perceptions of the built environment, including familiarity, exit affordances, and the location of safety, influenced their decisions on and actions toward exit routes during the emergency event. It is important for engineers to understand the factors that influence exit choice for two reasons. First, buildings or emergency procedures can be designed to account for this type of behavior—e.g., increasing the size of the main exit for certain type of buildings. Similarly, evacuation procedures can institute a plan whereby staff members direct individuals to exits that are less familiar or are unknown to many of the population. Second, an understanding of exit choice can aid the engineer in designing more efficient emergency communication systems. This may include specifically telling certain individuals which exits to use in the building or equipping potentially unfamiliar exits with flashing lights (see Kuligowski [83] for further information on better communication of emergency information during building emergencies).

Factor 4: The Influence of Leadership (or Role) on Behavior

This section focuses on the influence of leadership (or role) on evacuation behavior. Depending upon the building, leadership may already be in place before an emergency event begins. For example, in office buildings, there usually exist individuals in management positions throughout the building. Similarly, mercantile buildings often consist of customers and employees, some of whom are in management roles. However, in emergencies, leadership has been known to emerge as well [31]. In emergent cases, the individual (or individuals) did not hold a pre-emergency leadership role, but engaged in actions (i.e., helping behavior or the provision of instructions) that reflect a certain level of responsibility for others.

Jones and Hewitt, for example, studied group formation and leadership during the evacuation of a high-rise office building due to a fire [145]. Overall, a person's role in the organized hierarchy (pre-event leaders) had an influence on the group actions; i.e., in some cases, the leader's group listened, relinquished decision-making to this individual, and followed directions. The same type of scenarios were found in Kuligowski's study of the 2001 WTC evacuation [30] where individuals, more times than not, followed the instructions provided by their management of when and how to evacuate the towers. Jones and Hewitt did find exceptions to this trend, however, noting that when leadership failed to retain influence, new leadership emerged (i.e., even from those who were not previously in leadership roles).

Individuals also followed leadership in the King's Cross Disaster (discussed in the previous section) [144]. Individuals modified their action when they received instructions from people who appeared to hold official authoritative roles, i.e., police officers. In this disaster, even though the police did not have any additional official information and actually gave out incorrect information at times, they felt some responsibility for dealing with the situation and the public looked to them for instructions and guidance. In this particular instance, the reactions of the public to transportation staff was to ignore them, unless their instructions were backed by the police or fire department; showing that the people's confidence in the transportation staff was fairly low.

Engineering Implications of Leadership on Behavior

Leadership studies show the engineer that there are certain people in the building who are more likely than others to assume a leadership position during a fire emergency. These individuals are likely to provide suggestions on what to do, and in turn, influence others' actions. The more credible these individuals are, the more influence they will have on the rest of the population. For example, if the engineer is aware that managers are already more likely to respond and take leadership roles, another possibility is to assign fire safety leadership roles to people who are not already predisposed to help; i.e., empowering other types of occupants, in addition to managers, to enroll in key fire safety roles. Based on previous research, people with previous experiences in disasters or individuals with emergency-related occupations may already hold credibility as emergency experts with the larger population, and as an extension of this research, may be more likely to take interest in fire safety roles. Additionally, if the engineer understands that managers, for example, are already more likely to take leadership roles during a fire event, then managers should receive special fire safety training to ensure that they are providing accurate information and performing appropriate actions during building fires.

Factor 5: The Influence of Demographics (Gender) on Behavior

Demographics refer to the characteristics of a population, notably those characteristics that are genetic to the individual. Examples of genetic-based demographics are provided here: gender, age, physical fitness, physical abilities or disabilities, race, and culture. However, demographics can also include other social factors that can define or label an individual in some way, including socio-economic status, location (i.e., where s/he lives), marital status, occupation, etc. In this section, studies are presented that have been performed on one type of demographic (i.e., gender), and its effects on evacuation or emergency decision-making.

Bryan [14] and Wood [15] studied the influence of gender on certain residential evacuation behaviors. These researchers tested their respective datasets to see if gender had an influence on the first action taken, the action of fire fighting, and the act of notifying others in the building before evacuating.

First, with respect to initial actions taken, Bryan [14] studied the impact of gender. He found statistically significant differences between males and females in the categories of "searched for fire," "called fire department," "got family," and "got extinguishers." Male participants were predominant in fire-fighting activities: 14.9 % of the males participated in the behavioral response of "searched for fire" as opposed to 6.3 % of the females, and 6.9 % of the males were involved in the action of "got extinguishers" as opposed to 2.8 % of the females. In the U.S. population, females differed significantly from the males in the warning and evacuation activities—11.4 % of the females "called fire department" as their initial behavioral response action as opposed to 6.1 % of the males. In relation to the evacuation behavior, 10.4 % of the females "left building" as the first behavioral response action, contrasted with 4.2 % of the males.

Bryan [77] stated that the cultural influence of gender on female participants is probably explicitly indicated in the concern for other family members, with the finding that 11 % of the females "got the family" as the first behavioral response, whereas only 3.4 % of the males engaged in this behavioral response. It should be noted that the male actions of "searched for fire" or "fought fire" were matched by the female actions of "called fire department" and "got family." This identical pattern of behavioral responses has also been observed in fire incidents in health care and educational occupancies. However, considering the fact that these studies took place in the late 1970s and early 1980s, additional and updated research should be performed on these gender roles to test their current applicability.

In contrast, studies have been performed on building fires where gender was not identified as a predictor of behavior. For example, Proulx et al. [146] studied the 2 Forest Laneway fire in 1995, a high-rise apartment fire that killed 6 people in Canada. Researchers inquired about behaviors by distributing behavioral surveys to survivors, and found no significant differences between the actions taken by males and females.

Horasen and Bruck performed studies of response behavior of students in secondary (junior and senior high) schools [147]. Behavioral intention questionnaires; i.e., questionnaires that ask individuals what they would do if a particular situation were to occur, were completed by 170 students across grades 7 to 12. The first section of the questionnaire contained questions on student demographics, the second section presented students with six scenarios to collect information on the most probable actions taken under the given conditions, and the third section asked about students' previous experiences with evacuation drills and actual fire incidents. Overall, the study found no significant differences in likely behavioral responses of males versus females. However, when asked about scenarios in which they would be alone and with smoke cues, females were more likely to 'leave the building immediately', whereas males were more likely to 'find an extinguisher'. Saunders [148] studied an office building fire, also using behavioral intention questionnaires and found support for gender differences with respect to evacuation actions. Females were more likely than males to report that they would investigate, warn, and evacuate in response to various types of cues. However, neither males nor females wanted to fire fight. These studies may support research showing that women have a higher perception of risk in emergencies, and therefore, are more likely to respond in emergencies.

However, there are limitations associated with the use of behavioral intention questionnaires as a means to understand future behavior. In both studies described above, participants were asked to provide insight on what they would do in a series of hypothetical situations. Here, the participant is asked to mentally picture the scenario without physically being a part of the situation. If the scenario is not described in sufficient detail to the participant of the study, he/she will likely be unable to mentally picture the scenario accurately and make estimates of potential response behavior. Also, even if extensive detail is provided on the scenario description, behavioral intention questionnaires deprive participants from experiencing, first-hand, the cues from the physical (i.e., the fire) and social environments. The inability to experience the environment in the hypothetical scenario can cause difficulty in determining behaviors that would be performed, since it is the physical and social environments that prompt internal cognitions, decision-making and action in a fire emergency. Additionally, a participant's prediction of future behavior in a particular scenario may be influenced by previous experiences in building fires or other disasters. Thus, participants who have not experienced an actual building fire emergency may be less inclined to accurately predict response behaviors in future fire emergencies.

Engineering Implications of the Influence of Demographics (Gender) on Behavior

As mentioned earlier in this section, there are several demographic factors that could be considered as influential to behavioral actions during emergencies. Gender is simply one demographic factor that is highlighted here in this chapter. While it is important for engineers to understand that demographics can play a role in behavioral response during building fires, engineers must also understand that the relationship between demographics and behavior is complex [133]. Engineers should be aware that individual factors are more likely to be predictors of internal cognitions (such as risk perception), which then influence action, rather than direct influences of action. Rather than stating that all women warn others during fire emergencies, what is more likely to be the case is that situational or emergency-related variables, such as environmental cues and demographics, lead to risk identification and assessment, which then leads to action. Therefore, engineers should inquire how gender and other individual-based factors influence perceptions of the threat and risk, which then directly influence actions performed in response to a fire.

Summary—Behavioral Facts

A great deal of information has been provided on human behavior in fire in this chapter. Following each section, engineering implications were discussed, providing the "so what?" to readers. The engineering implications were provided after each section so that a reader might be able to see the application of these findings to actual engineering projects. In addition, examples of "behavioral facts," first introduced by Kuligowski and Gwynne [149] and extended by Gwynne [150], are listed below to summarize the major findings captured by this chapter, which link to the section in which each fact is discussed. A total of 11 behavioral facts are listed here:

Behavioral fact #1: *Rather than panic, people's first instinct is to feel (sometimes inappropriately) safe in their environment (Sections "Discarded Theories of Human Behavior in Fire" and "Panic Behavior").*

Behavioral fact #2: *Just because information is provided in a fire emergency does not mean that appropriate occupant response will take place. Perception of, attention to, and comprehension of information (in a fire event) is a critical part of occupant response (Section "Social Psychological Theories of Human Behavior in Emergencies").*

Behavioral fact #3: *Occupants must perceive a credible threat and personalize the risk before protective action is taken (Section "Social Psychological Theories of Human Behavior in Emergencies").*

Behavioral fact #4: *People will engage in information seeking actions, especially when cues are ambiguous and/or inconsistent (Sections "Social Psychological Theories of Human Behavior in Emergencies" and "Relating Theory to Practice—Protective Actions in Fires").*

Behavioral fact #5: *People are likely to engage in preparation activities before beginning evacuation response. Preparation activities will likely delay their response (Section "Relating Theory to Practice—Protective Actions in Fires").*

Behavioral fact #6: *Generally, people act rationally and altruistically during building fires (Section "Relating Theory to Practice—Group Behavior").*

Behavioral fact #7: *The surrounding population will influence the individual's decision-making process (Section "Factor 1: The Influence of Other Occupants on Behavior [Social Influence]").*

Behavioral fact#8: *Stress can narrow a person's field of perception, causing individuals to miss or ignore certain cues or information* (*Section "Factor 2: The Influence of Stress on Behavior [Perception])*".

Behavioral fact #9: *People move to the familiar. The relationships with the structure and people that existed prior to the incident influence response during the incident* (*Sections "Relating Theory to Practice—Group Behavior"* and *"Factor 3: The Influence of the Built Environment on Behavior"*).

Behavioral fact #10: *People do not instantaneously switch to a different set of roles in a building fire event. The rules and roles prior to the event form the basis of those employed during the event* (*Section "Factor 4: The Influence of Leadership [or Role] on Behavior"*).

Behavioral fact#11: *People are heterogeneous and these individual differences in characteristics* (*or demographics*) *can influence behavior* (*Section "Factor 5: The Influence of Demographics [Gender] on Behavior"*).

What Is Missing in Human Behavior in Fires?

This chapter first presented an overarching theory of human behavior in disasters; i.e., the period of time in which individuals make decisions on whether protective action is necessary and then which actions they will take in response to the threat (the PADM). However, this theory is more general in nature and does not actually identify the factors that would predict the performance of particular actions, such as helping others or taking a particular route in the building. Next, this chapter presented studies from the field of human behavior in fire to support the larger, general theory. These studies identified the actions that people take in response to fires, the approximate timing of action types, as well as began to identify the factors that influenced these types of actions. Most studies focused on the pre-evacuation period of a building fire.

What is missing in the field of human behavior in fires is a comprehensive theory that brings all of the theory and data from studies together to predict, rather than to simply determine based upon user input, human behavior during evacuations. With a larger comprehensive theory, engineers could perform more accurate calculations for performance-based design (i.e., see Chaps. 57, 59, and 60) and model developers could create more accurate evacuation models that rely less on user input and more on fundamental theory (see Gwynne [150]).

One step in the process of reaching this comprehensive theory is to develop models that can predict *the actions that people take in response to fires*—both before they decide to evacuate (pre-evacuation) and during the evacuation (or movement) time period. Canter, Breaux and Sime's [78] decomposition diagrams begin to tie various sub-theories together, but focus primarily on the linking of evacuation actions together, and often neglect to identify the interpretations and levels of risk perception that are influential to occupant's actions.

One example is provided here of a qualitative model that predicts the pre-evacuation actions of survivors of the 2001 World Trade Center (WTC) Disaster [30, 151]. Through analyses of transcripts from 245 face-to-face interviews with survivors from both WTC towers, collected by Project HEED [22], this model is the first inductively-developed, individually- (or -evacuee-) based model explaining the actions taken during the pre-evacuation period of a building fire/evacuation event. The goal of this research was to describe evacuation decision processes in greater detail than either research on building fires or studies on community-wide evacuation, focusing on how people perceive and interpret environmental cues and warnings, how they seek confirmation during sensemaking and milling processes, and what they do before moving to safety.

There are five main findings that can be highlighted from this research. The findings are as follows:

- The WTC pre-evacuation period was divided into two main phases: the milling/sensemaking phase and the protective action phase. In the milling/sensemaking phase, WTC occupants engaged in two different actions—continuing to work or seeking additional information. In the protective actions phase, on the other hand, occupants engaged in actions that were focused specifically on protecting themselves or others (i.e., helping others, preparing to evacuate, or defending in place). Both phases took place before moving to the stairs or elevators.
- Risk perception, or the feeling of personal danger, was the main predictor of when individuals decided to evacuate—i.e., the transition from the milling/sensemaking phase to the protective action phase. Both individual and environmental factors were identified as influential of risk perception development.
- Some individuals made their decisions to evacuate before others on their floor. These "early responders", as labeled by Kuligowski [30], were primarily higher-level managers, fire wardens, military personnel, or individuals with experiences or occupations in emergency situations. These individuals still required the receipt of information that increased their level of perceived risk, but were also more inclined to act first (before others) because they felt responsibility for others and/or had previously experienced/witnessed negative consequences associated with fire or building evacuations.
- Certain factors, such as personal responsibility, social connections, and the actions of others, influenced which protective actions people engaged.

See Kuligowski [30] for further explanation on the conceptual model.

Kuligowski's model is not without limitations, however. The model focuses specifically on the pre-evacuation period of one building event. Additionally, the model does not incorporate any decisions or actions of the decedents. While the findings in the model were verified with theory from other events, the factors that influenced each action performed were specific to an office building fire and subsequent evacuation, thus making it difficult to generalize the findings. This is a first start to developing a model to predict actions taken during building fires; however, this effort should be expanded upon to include findings from analysis of other building fires, including fires in different types of structures and with different populations, as well as from analysis of other types of disasters, not limited to building fires.

An additional step in the process of reaching this comprehensive theory is to develop models that can predict *the timing associated with the performance of certain actions*—both before they decide to take protection (e.g., evacuate) and during the evacuation (or movement) time period. First, there are a few studies that attempt to predict how long people delay before evacuating [1, 40, 84, 152] as well as the time it takes individuals to evacuate via stairs [1]. For example, NIST's federal investigation of the 2001 WTC disaster performed multiple regression analysis to predict pre-evacuation delay and normalized stairwell evacuation time—identifying factors such as action type, floor number, the number of environmental cues and level of perceived risk as predictors of pre-evacuation delay time and factors such as the presence of counterflow, the presence of crowding, the number of environmental cues, floor number, pre-evacuation delay, and evacuation interruption as predictors of normalized stairwell evacuation time [1].

Other research efforts have attempted to quantify human behavior in the form of an empirical model. One such model was developed by NIST [153] based upon the WTC conceptual model [30], presented earlier in this section. A first-order quantitative model, labeled as the Evacuation Decision Model (EDM), was developed to predict the time when a simulated occupant, or agent, decides to evacuate (i.e., the decision that protective action is necessary). In the EDM, the prediction of the evacuation decision is based upon the agent's perceptions of risk during the pre-evacuation period. In its simplicity, the EDM model attempts only to simulate the evacuation decision, without additional simulation of protective action behaviors.

At present, these qualitative and quantitative models scratch only the surface of the development of a larger, comprehensive model of human behavior in fire. These models provide a path forward on the methods that could be used in its eventual development. However, there is much work still to be done to improve our understanding of human behavior in fire, and without this understanding, a comprehensive model is near impossible. Listed here are just a few examples of areas in the field that require further study:

- The influence of fire's toxic products and heat on decision-making and behavior (before incapacitation or death occur) in a building fire
- An identification of all of the factors that influence risk perception and how they interact to increase or decrease risk perception levels.
- The types of protective actions that are performed in building fire evacuations
- The factors that influence the various types of protective actions performed in building fire evacuations
- The factors that influence the receipt of cues, the ways in which people pay attention to cues, and the comprehension of cues
- The ways in which individual factors, such as gender, disability, age, body size, culture, marital status, past experiences, training and social role, influence decision-making during building fires
- The timing associated with the performance of behavior during building fires, and the factors that influence this timing
- The influence of urgency or other types of dissemination techniques on the response of building occupants during fires
- The influence of group dynamics on individual decision-making and group decision-making during fires
- The role of place (including building type or building characteristics) on decision-making during fires
- The role of psychological states, including stress or anxiety, on decision-making during building fires.

For the field to reach its goal and develop a larger understanding of human behavior in fire, accurate, rigorous, and comprehensive research must continue. There is still much left to understand, but the ultimate goal of a comprehensive model is in our future.

Chapter Summary

Human behavior in fire is a key aspect of understanding and designing for life safety in building fires. However, the treatment of human behavior in performance-based design analyses often times falls short by ignoring, oversimplifying, or inaccurately accounting for it. Relationships in human response are complex; though, these relationships are not impossible to describe or even predict. The chapter began with a description of three disaster myths, which, if accurate, would make it easier for the field to surrender and admit defeat against the task of predicting human behavior in fire. However, the occurrence of panic, disaster shock, and group mind are rare in fire emergencies; and with this realization, comes an understanding that real patterns of behavior should be identified when studying human response to fires. These patterns are clearly displayed in the PADM, also introduced in this chapter, which describes the process by which individuals make decisions and respond to disaster situations. Patterns are also identified by the studies weaved throughout this chapter—identifying the role of group dynamics, social influence, stress, the built environment, leadership/status, and demographics on behaviors performed by occupants in response to a fire emergency.

Following each section, the author presented the "so what?" or the "who cares?" to the reader. The purpose here was to make clear why this information is important and what influence these various aspects of human behavior in fire have on life safety and building design. All of the information presented in this chapter should be considered by an engineer performing a life safety analysis and/or developing evacuation procedures for building occupants in fire emergencies. In some cases, data are available that makes this consideration easier, and in other cases, the engineer must use appropriate and technically-sound judgment and decision-making.

The fire field recognizes the need for a comprehensive theory of human behavior in fire, and researchers around the world are working on various aspects of the problem to make this a reality. This theory would then be incorporated into standard engineering tools, so that human behavior in fire can no longer be ignored or discounted in performance-based analyses. Until this occurs, the onus is placed upon engineers and review authorities to ensure that building occupants are accounted for and protected. It is the hope that the results of performance-based analyses are significantly enhanced by the information included in this chapter as well as the suite of egress-related chapters available in this edition of the handbook: design strategies (Chap. 61), egress data (Chap. 64), the design of egress scenarios (Chap. 57), hydraulic modeling (Chap. 59), evacuation modeling (Chap. 60), toxicity (Chaps. 63 and 62), and smoke effects (Chap. 61).

Acknowledgements This chapter is dedicated to the late Dr. John L. Bryan (Prof), who authored this chapter in the previous four editions of the handbook. Dr. Bryan provided mentorship and guidance to so many in the field, including the author of this chapter. He is deeply missed. Dr. Kuligowski would like to thank all of the reviewers of this handbook chapter, including Paul Reneke, Jason Averill, Thomas Cleary, Anthony Hamins, Howard Harary, and Steven Gwynne, all of whom provided insightful comments. Also, special thanks to Elizabeth Landry for help with chapter editing and formatting.

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