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A decision model for recommending which building occupants should move where during fire emergencies

Norman E. Groner

John Jay College of Criminal Justice, City University of New York, 524 West 59th Street, New York, NY 10019, United States

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ABSTRACT

This paper describes a decision model for managing the movement of building occupants during fire emergencies. Currently available guidance from standard practice, egress modeling, codes and the research literature, is too general to provide much help to persons charged with the responsibility of where groups of occupants should be located given a fire scenario. The *occupant movement decision model* described in the paper uses three basic yes–no questions to divide building occupants into groups during a fire emergency. For any particular group, the decision model recommends one of two basic actions: (1) people remain where they are already located; or, (2) people relocate to a safer area in or outside the building, including the means by which they should travel to the new recommended location. The model specifies informational inputs that are used to decide which strategies are best used for which occupant groups—both in planning the emergency and for maintaining the situation awareness needed to adapt the plan when situations evolve in unexpected ways. By clearly determining which occupants should use which strategies, the model yields more effectively tailored strategies than those commonly prescribed for building-wide strategies of full and phased building evacuations, partial building evacuations, in-building relocations, and sheltering-in-place.

1. Introduction

Persons responsible for managing a fire emergency may lack a clear understanding of how they should move occupants in response to a fire given the fire protection features of a building and the capabilities of its occupants. This paper describes an *occupant movement*[1] *decision model* intended to assist those people. The normative decision model[2] described here is used first, to divide building occupants into groups, and, second, to recommend an appropriate protection strategy for each group. Each group is provided with a recommendation to either remain in their present location or to move to a safer location. If people are asked to move, then the means (i.e., routes and assistance) by which they are expected to travel to the safer location can be provided. While the decision model is primarily intended for persons who will direct the movement of people, it value to fire safety systems designers (e.g., fire protection engineers and architects) who are expected to recommend effective egress strategies appropriate to the occupant capabilities and the physical fire safety and layout features of specific buildings.

Occupant movement strategies are often categorized using schemes similar to the following: [1]

- Simultaneous whole building evacuations. All occupants leave the building at the same time when they are notified.
- Phased whole building evacuations. All occupants leave the building, but in a phased sequence based on the vulnerability of building occupants.
- Partial building evacuations. All occupants in a certain part of the building leave.
- Relocating people within a building. Persons in the building relocate to safer areas.

However, in many large buildings, these approaches are oversimplified. A combination of strategies should be recommended to different groups of occupants depending on the factors discussed in this paper. For example, in a tall building, persons above and below the fire zone may be requested to remain where they are already located and evacuate the building if necessary (defend-in-place with a partial building evacuation as backup), persons in the fire zone may be requested to move below or above the fire zone

E-mail address: ngroner@jjay.cuny.edu

[1] To avoid confusion, this paper uses the term "occupant movement" because people may be advised to remain in their present locations or to move to a different location in the same building. The terms "evacuation" and "egress" are sometimes used when referring to all movement of people during emergencies, but in many other contexts these terms imply that people move to the outside of a building.

[2] In contrast to descriptive models, a normative "model" is a prescriptive decision model that is used to evaluate alternative solutions to a problem.

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(relocate), and persons with disabilities may be requested to move to refuge areas to await rescue (relocate, defend-in-place, and rescue if necessary).

1.1. Some investigations of fires implicate poor managerial decision making that contributed to large losses of life

Because persons charged with the responsibility of managing a fire emergency often lack a clear understanding of the logic underlying fire protection features, it is not surprising that they make mistakes when responding to emergencies. Unfortunately, these mistakes are rarely revealed because investigations of fires focus on problems with physical systems—shortcomings in code provisions or maintaining systems mandated by codes. Even when mistakes are made, they are often attributed to "panic" instead of attempting to understand the mistaken logic that provided the erroneous rationale for these mistakes. However, there is evidence where managerial mistakes contributed to the severity of fire incidents. A high rise office building fire in Chicago resulted in several fatalities attributable in part to errors in managing the movement of building occupants [2]. Chertkoff and Kushingian [3] document fires where delayed and poor managerial decision-making may have contributed to large losses of life. These included (1) managerial delays in starting an evacuation caused by a fear that occupants would "panic," and (2) the unavailability of people to guide occupants to safe egress routes. Chertkoff and Kushingian explain that, in addition to poor decision making in response to fire, building management also failed to understand how pre-conditions such as highly combustible interiors and convoluted and blocked egress routes greatly increased the risks if a serious fire were to occur.

1.2. A simple mental model might improve decision making for the movement of building occupants in response to fire

Sophisticated education and training would certainly improve the responses of occupant movement managers, but it seems unlikely that a great increase in resources will be dedicated to that purpose. However, a simple *mental model*[3] should help occupant movement managers avoid mistakes in both planning for and responding to fire emergencies. Such a mental model might help people managing the movement of occupants to better understand how strategic responses to fires can take advantage of building features and to compensate for human limitations under a range of potential scenarios. The occupant movement decision model described in this paper serves as a mental model that is easily understood and recalled with relatively little fire safety education and training.

1.3. Existing recommendations about managing the operational responses to fire emergencies are too general

There are references that describe the *general* issues about planning to manage responses to fire emergencies. Examples include the *Life Safety Code* [4] where detailed recommendations are available for conducting required life safety assessment in assembly occupancies. Burtles [5] has published a guide based on the process of business continuity planning. In England and Wales, occupancy-specific "fire safety documents" are available online [6]. The Building Owners and Managers Association has published useful but general guides to emergency planning [7,8]. Extensive coverage is available that describes the logic that underlies the physical design of building features that enable the safe movement of people [1], but there is little guidance about how physical systems should be leveraged when making operational decisions about moving people during fire emergencies.

1.4. Computational models of egress times have limited value in managerial decision making for occupant movement during a fire

A rich body of research and development deals with the development of models that calculate travel times during fire emergencies. Calculated egress times derived from these evacuation models are used to design egress systems that ensure adequate carrying capacities to evacuate building occupants.

Computational predictions for building evacuation times generally compare Required Safe Egress Time (RSET) to Available Safe Egress Time (ASET). Depending on a selected scenario (the design fire and the numbers, locations and capabilities of building occupants), the margin of safety provided by a building's physical features is calculated as the amount of time that available safe egress time exceeds the required safe egress time. The available safe egress time is derived from engineering models of fire growth that measure the amount of time before a space becomes untenable, a function of heat, visibility and smoke toxicity [1]. As an example, ASET for a given space ends when a layer of smoke descends to a height where building occupants may not survive.

Fire protection engineers widely apply computational egress models to performance-based design solutions. The ASET/RSET approach guides the design of physical systems that facilitate the movement of people in buildings, especially the design of egress system. Nonetheless, the approach has important limitations.

- Well-managed occupant movement should use a more conservative (but very difficult to measure) objective, for example not to expose people to conditions where they feel their lives are in immediate jeopardy.
- Older simulation models generally treat people as physical objects, ignoring their cognitive attributes and lack of information about available egress routes, both important determinants of actual behavior. Therefore, these models often calculate optimal times, assuming that people follow the quickest safe route, and thereby underestimate actual evacuation times. Beyond the speeds at which people are expected to move, recent innovations are extending the approach to include the cognitive attributes of people, including pre-evacuation times (i.e., that amount of time the people take before beginning their movement toward egress routes) and interactions of individuals with their environments, including egress familiarity, fire hazards, other people and physical features such as building layouts, and the visibility of exit signs [9,10].
- Simulation models have either excluded or been very limited in their ability to incorporate the *variable and adaptive* behaviors of building occupants [9].
- Using computational models to optimize the design of egress routes often requires a tedious process of comparing various configurations, fire scenarios and assumptions about the locations and capabilities of building occupants. Recent innovations may provide more efficient computational methods to finding the most efficient strategies for moving people [11]. Even if we assume that entirely valid means to computationally model optimal occupant movement strategies are forthcoming, *realizing the potential is impossible without some way of conveying this information to the persons responsible for managing the movement of occupants.*
- Central to the concerns addressed in this paper, these computational models do not include the decision processes of the

[3] "Mental models" are simple beliefs that people have about how something works in the real world. To the degree that mental models accurately represent the real world, people are less likely to make mistakes.