NBSIR 79-1906

The Evacuation of Non-Ambulatory Patients from Hospital and Nursing Home Fires: A Framework for A Model

John Archea*

(Stephen T. Margulis, Editor)

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

November 1979

Prepared for

Program for Design Concepts
Center for Fire Research
National Engineering Laboratory
Washington, D.C. 20234

Sponsored by

Public Health Service
U.S. Department of Health, Education and Welfare

*Currently at the College of Architecture
Georgia Institute of Technology
Atlanta, Georgia 30332

NBSIR 79-1906

THE EVACUATION OF NON-AMBULATORY PATIENTS FROM HOSPITAL AND NURSING HOME FIRES: A FRAMEWORK FOR A MODEL

John Archea*

(Stephen T. Margulis, Editor)

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

November 1979

Prepared for
Program for Design Concepts
Center for Fire Research
National Engineering Laboratory
Washington, D.C. 20234

Sponsored by
Public Health Service
U.S. Department of Health, Education and Welfare

*Currently at the College of Architecture
Georgia Institute of Technology
Atlanta, Georgia 30332

U.S. DEPARTMENT OF COMMERCE
Luther H. Hodges, Jr., *Under Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENTS

The report is a product of the HEW/NBS Fire and Life Safety Program, sponsored by the Public Health Service of the Department of Health, Education and Welfare (HEW). This program is a joint effort of HEW and NBS (National Bureau of Standards) to develop rational, technically sound solutions to fire problems in health care facilities. In addition to the types of work described in this report, the joint program has produced products in the areas of: decision analysis, fire and smoke detection, smoke movement and control, automatic extinguishment, and behaviors of institutionalized and other populations in fire situations.

The author extends his appreciation to Dr. Stephen T. Margulis, Dr. Fred I. Stahl and Dr. Robert Wehrli for their generous contributions of substantive and editorial suggestions on an earlier draft of this manuscript. A very special note of thanks is extended to Candace Roat for her sustained contributions and for her many helpful comments and suggestions on the earlier draft. The author's draft was edited into the present report by Dr. Margulis. The editor wishes to thank the author and his colleagues in the Center for Building Technology for their helpful comments. He also wishes to thank Miss Tracey Kistler for the typing of this report.

ABSTRACT

This report is directed toward the problem of evacuating dependent, non-ambulatory persons from fires in nursing homes and other health care facilities. It deals only with those behavioral and building factors that bear on the activities that follow directly from a decision to evacuate patients from a fire zone in a nursing home or similar facility. The examination is based on the rejection of the model which is the basis for current life safety regulations because it assumes independent occupant mobility. This assumption does not apply to dependent, non-ambulatory persons. The major objective of the report is to identify those factors that must be considered in order to determine the ideal performance of a hospital or nursing home evacuation system for non-ambulatory patients when all components or persons in that system act as they are designed or trained to act. These factors are presented as part of an analysis of evacuation as a five phase process: manpower supply phase, patient preparation phase, patient removal phase, rest and recovery phase, and manpower resupply phase. Research findings are reviewed and a research agenda is proposed.

Key words: Building codes; building evaluation; elderly; fire safety; handicapped occupants; health care facilities; nursing homes; user needs.

INTRODUCTION

Current fire safety regulations which affect the design of egress or protection systems in buildings are generally based on the assumption that the building occupants are able-bodied, ambulatory, and reasonable individuals. These regulations do not consider the predicament of building occupants who are not able-bodied, who are non-ambulatory, and who may be the victims of cognitive deficits, such as bed-ridden patients in hospitals or nursing homes, or the handicapped. That is, current fire regulations have given virtually no consideration to building occupants who cannot evacuate or protect themselves during a fire emergency and who must have the assistance of other persons before they can realize the benefits of most evacuation or fire protection systems (Caravaty and Haviland, 1967; Lefer, 1976). This report addresses the problem of evacuating highly dependent or non-ambulatory patients from fires in nursing homes and other health care facilities.

A growing body of research and analyses indicates (1) that current regulations underestimate the number and/or width of exit routes that would be necessary to complete a total evacuation of a densely occupied building in the required time (Pauls, 1975; Stahl and Archea, 1977); and (2) that current regulations are based on assumptions about human behavior during fire emergencies that are inadequate (Bickman, 1977; Bryan, 1976; Canter and Matthews, 1976; Lefer, 1976; Lerup, 1975; Wood, 1972). Thus, new behavioral evidence may force a reconsideration of regulations concerning evacuation route requirements and may require regulations to take into account the impact of building occupants' behavior on the effectiveness of fire protection systems during fire emergencies. This report addresses both design and behavioral factors, specifically those design and behavioral factors that can affect the activities that follow from a decision to evacuate patients from a fire zone in a nursing home or health care facility. Without an understanding of human behavior in fire emergencies, egress-related physical design and emergency planning (drills, training, educational programs) may not be effective in assuring the evacuation of all occupants safely during a fire emergency.

Nature of the Report

The report discusses building, patient and staff factors that influence the evacuation of non-ambulatory and dependent patients of nursing homes and health care facilities following the decision to evacuate. It does not consider activities that precede the decision to evacuate, the process by which that decision is made, nor the manner in which the decision is communicated to others. Activities other than evacuation itself, such as fire fighting or sending a fire alarm, are considered only as they relate to the evacuation process itself.

The major objective of this report is to identify those factors which must be considered to determine the ideal performance of a hospital or nursing home evacuation system for non-ambulatory patients when all components or factors in that system perform as they are designed or trained to perform. This report is best characterized as a comprehensive, but conjectural, problem statement that is constrained by the results of relevant research. It is not presently an operational guide for the conduct of fire emergency evacuations. Although the report is, to a large degree, conjectural, the text tends to avoid conditional and qualified statements in favor of declarative assertions. When relevant research is being cited, it is referenced.

Organization of the Report

Chapter 1 presents a step-by-step derivation of the major factors involved in evacuating non-ambulatory patients during hospital or nursing home fires. The chapter is theoretical, conjectural; however it is consistent with current research reviewed in Chapter 5. Each section in Chapter 1 has a corresponding schematic diagram to illustrate the factors and their interrelations that are discussed. The major factors are cast as five sequential phases of an evacuation process in Chapter 2. The major patient, staff and building factors that can influence the activities of each phase are introduced in Chapter 2. Examples of these factors are also presented. Four parameters, necessary for integrating the five phases into a working model of an evacuation system for non-ambulatory patients, are introduced and discussed in Chapter 3. Although available data are insufficient to support the development of a definitive model of the evacuation process, Chapter 3 presents factors that would have to be considered in developing such a model. Chapter 4 considers the design and assessment of evacuation systems. The chapter is predicated on the assumption that any analysis of the evacuation process, ultimately, is a matter of measuring initial conditions and system performance. Fourteen assumptions are introduced, representing approximations of initial conditions and performance measures, as guidelines for the design and assessment of evacuation systems. Because there is limited research on the movement of non-ambulatory patients in nursing homes and health care facilities and because this information is critical to the development of a definitive model of patient evacuation, a research agenda in proposed in Chapter 5. This chapter also reviews the available research on behavioral aspects of fire evacuations from buildings. The final chapter, Chapter 6, summarizes the report.

1. DEFINING THE PROBLEM

This chapter presents the special problems of non-ambulatory patients during a fire emergency in the building they occupy. The chapter considers the problems introduced by the non-ambulatory patient's need for help from others and the problems faced by those who attempt to provide the needed assistance during the emergency. These problems show the limitations of the currently accepted model of the uninterrupted flow of able-bodied evacuees through fire-protected means of egress. The research which support the ideas developed in this chapter appears in Chapter 5.

1.1 THE HYDRAULIC MODEL

Most current building egress regulations are based on what might be called a "hydraulic model." This model makes three important assumptions: (1) building occupants are alert, able-bodied and ambulatory; (2) fire safety depends on the "safe end" of the evacuation system--the protected stairwells and exit doors that mark safe exiting during a fire emergency; and (3) there is high density building occupancy which, during a fire emergency, limits the reasonable options for evacuation that are available to building occupants. Given these assumptions, the hydraulic model defines the building evacuation process as a two-phase process. The hydraulic model is illustrated in Figure 1.[1,2] The first phase, the "start up" phase, consists of an immediate, appropriate, self-initiated movement toward the nearest exit by the building occupants, given a decision to evacuate a building during a fire emergency [SS, for "self starting"].[3] Self-initiated movement means that the occupant does not require any assistance from others to initiative his or her evacuation. The second phase, the "egress" phase, consists of a deliberate progression toward the exit, with each occupant moving under his or her own power, in tight formation with the other evacuees [SE, for "self evacuating"]. The model suggests there should be no surges or queues, just a constant use of the exit channel at or near capacity until the last occupant safely clears the exit. In both phases, no interaction or interdependence between evacuees is considered.

---

[1] Each of the six sections of this chapter has its figure. Each figure maps the factors and their interrelations that are discussed in its section. Figure 7 summarizes the factors and their interrelations for the entire chapter.

[2] The reader should carefully review the introductory statement in Appendix 1 before studying the figures in this chapter.

[3] Symbols, such as SS, which appear in brackets, are used in the figures. Each symbol represents a different factor. Each symbol introduced in a section will first appear in the figure for that section and will reappear in other figures as indicated in the Key in Appendix 1.

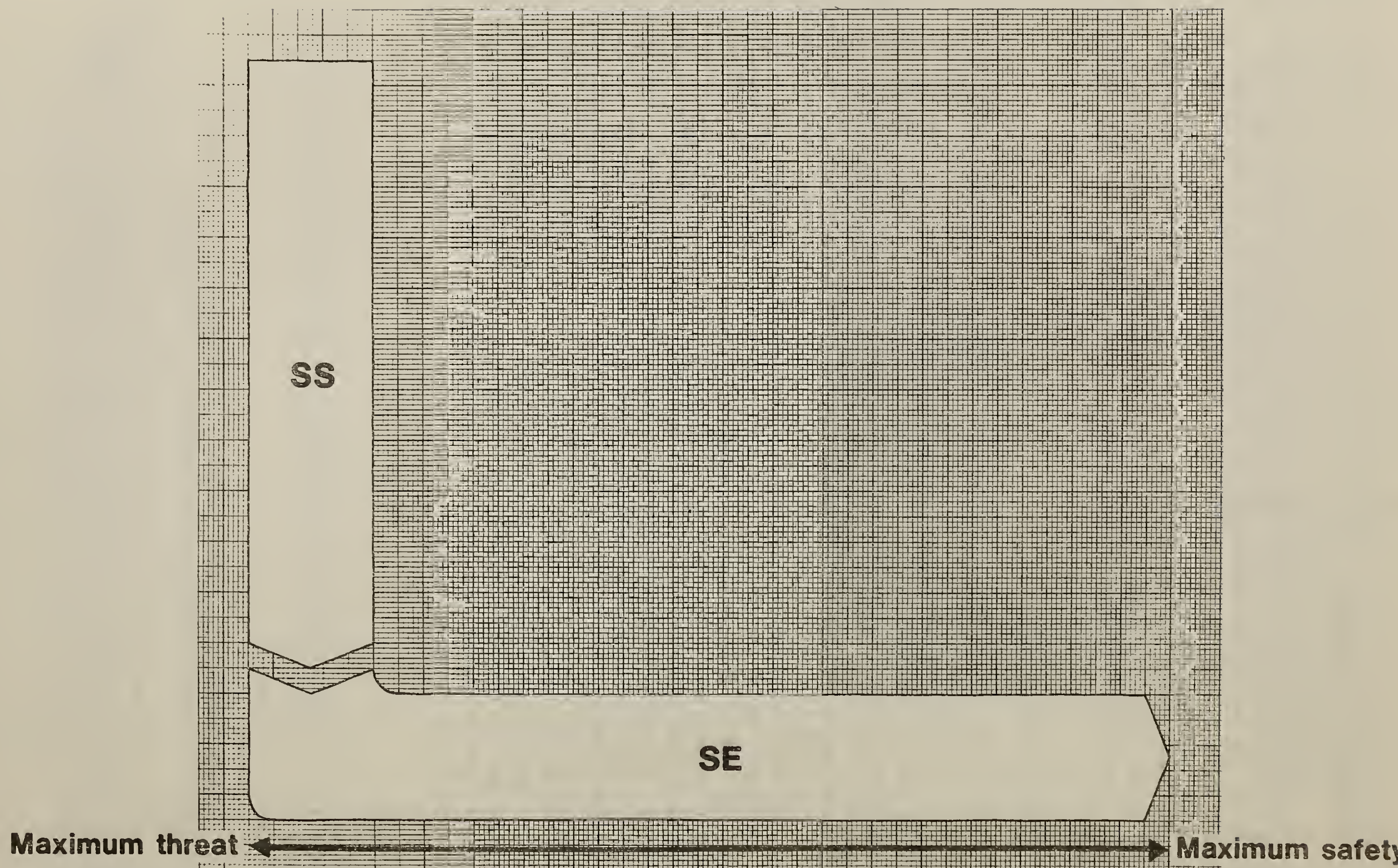

FIGURE 1: THE HYDRAULIC MODEL, WHERE (SS) IS THE SELF-STARTING ACTION OF INDEPENDENT, AMBULATORY PATIENTS AND (SE) IS THE SELF-EVACUATING ACTION OF INDEPENDENT, AMBULATORY PATIENTS.

The key to evacuation is the maximization of occupant discharge at the exit or "safe end" of the evacuation route. For this reason, the measure of overall system performance is the flow at the building exits.

1.2 NON-AMBULATORY PATIENTS

The dependent patients in nursing homes and other health care facilities present problems during fire evacuations that violate the assumption of independent occupant mobility, a cornerstone of the hydraulic model. This violation arises if a building occupant is non-ambulatory, cannot maintain the movement speed of able-bodied occupants, or interferes with the ability of others to move on the same route. Non-ambulatory patients may not reach the safe end without assistance from others. They may not even be able to initiate an evacuation effort because they cannot leave a bed or a chair unassisted. Without self-initiated movement and uniform self-evacuation, emphasis on the safe end alone is insufficient [s, for "safe end"].

It is assumed that whenever non-ambulatory persons are considered, the analysis of the evacuation process during a fire must shift from the safe end to the "threatened end" of the evacuation route [t, for "threatened end"]--the point from which the non-ambulatory patient who is, presumably, near the path of the fire or its products must begin his escape. Instead of self-initiated start-up, deliberate preparation of the patient for evacuation must be considered.

This "preparation" process involves at least two people: a non-ambulatory, therefore dependent, patient and one or more assistants or helpers who, at the beginning of a fire evacuation of a nursing home or health care facility, are likely to be nursing home or hospital staff and fire-fighters. This is illustrated in Figure 2. (It is recognized that patients without mobility problems may be dependent on assistance for other reasons. However this paper focuses on those with mobility problems.)

During the preparation process, the requirements of the self-starting patient group [SS, for "self-starting"] are largely consistent with the assumptions of the hydraulic model. However, the non-ambulatory patients are dependent upon the assistance of others, and, as a consequence, they introduce several factors affecting evacuation.

The first factor is the preparation assistance required by each non-ambulatory patient [PR, for "preparation required"]. This depends on a patient's mobility status, medication, dependency on fixed life-support system, and on prosthetic appliances to sustain movement. Preparation covers everything from awakening a sleeping patient to dragging to safety a comatose patient who has been wrapped in a wetted sheet.

The second new factor is the level of preparation assistance that can be provided for each patient [PP, for "preparation provided"]. This involves the training and competence of the helpers, such as staff, to perform under the stress of a fire emergency, the tasks that compete for

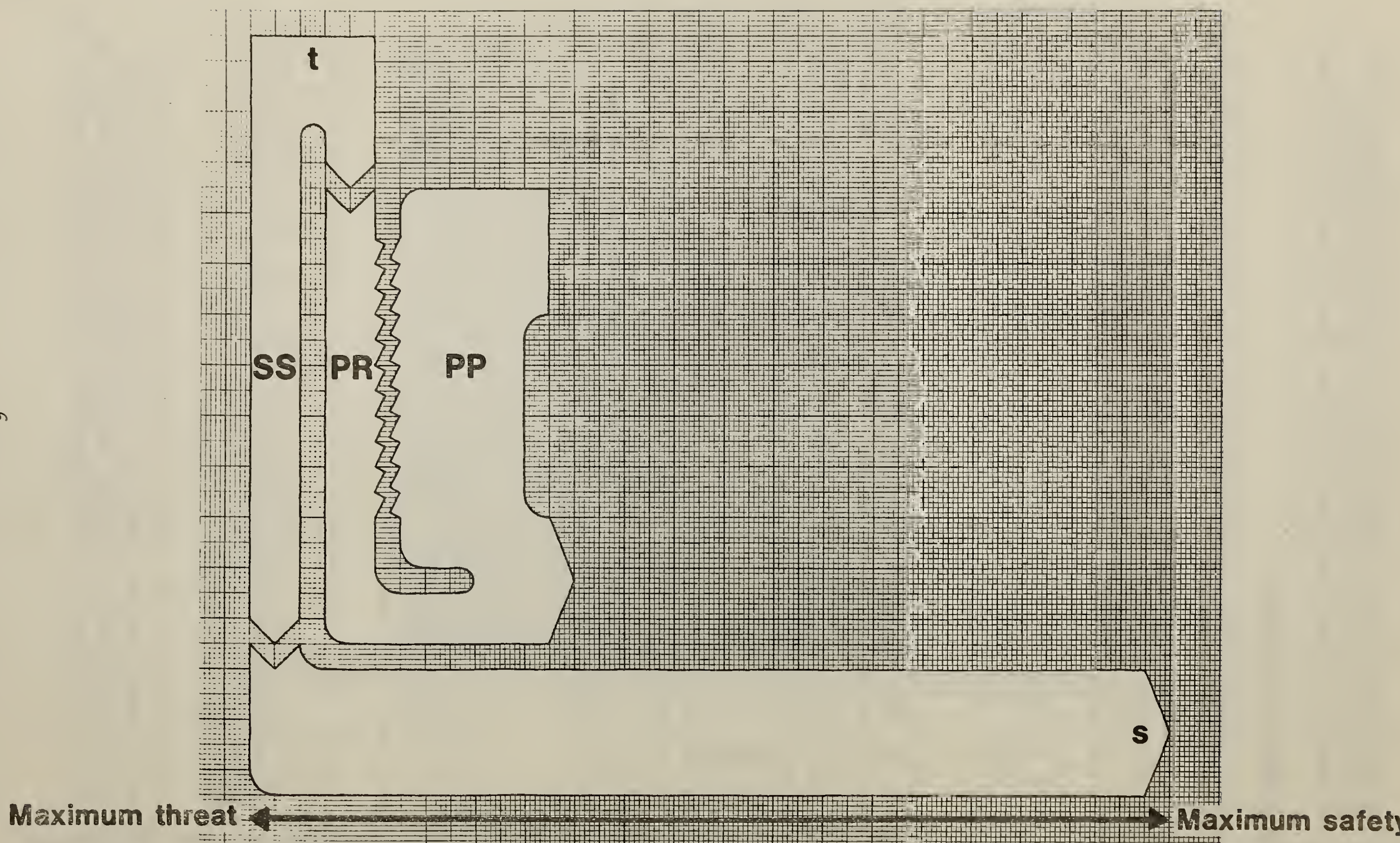

FIGURE 2: NON-AMBULATORY PATIENTS, WHERE (s) IS THE 'SAFE END' OF THE EVACUATION ROUTE; (t) IS THE 'THREATENED END'; (SS) IS THE SELF-STARTING ACTION OF INDEPENDENT, AMBULATORY PATIENTS; (PR) IS THE PREPARATION REQUIRED OR RECEIVED BY DEPENDENT PATIENTS; AND (PP) IS THE PREPARATION PROVIDED BY TRAINED ASSISTANTS.

staff attention during an emergency, and the availability of needed equipment. The preparation process can be ineffective if the assistant cannot handle a wheelchair transfer or does not have a needed stretcher.

The third factor is the conditions under which preparation tasks must be performed. Conditions such as the exposure to risks, time limitations, the availability of intermediate fire protection systems and the layout of the workplace can affect the patient's cooperation, the helper's performance and the levels of stress imposed on both patient and assistant.

In short, the preparation task is a collaborative interaction between two people, one of whom, the non-ambulatory patient, is almost entirely dependent upon the other. This collaboration, however, is influenced by the entirely different costs and benefits each faces from the success or failure of the collaboration. These differences in outcomes and their evaluation provide the context for many crucial decisions during evacuation.

1.3 REMOVAL FROM THE THREATENED ZONE

When the preparation task is completed, the process of actually removing patients begins. This is illustrated in Figure 3. At this point, the patient population can be classified as those who can proceed toward the exit on their own [A, for "ambulatory"] and those who cannot. The latter, who require continued assistance, include the non-ambulatory patients [NA, for "non-ambulatory"]. The ambulatory patients are grouped with the self-starting self-evacuators who do not require assistance during the preparation process.

The ambulatory group includes patients who are not fully ambulatory in the sense presumed by the hydraulic model. They may move slowly, pause occasionally to rest, or not proceed directly to the exit. Some may use prosthetic appliances which could interfere with the escape of other evacuees. As a result, the overall speed of movement is likely to be considerably slower than if the population was fully able-bodied and the rate of flow will be less uniform. Moreover, the not-fully-ambulatory patients will be less likely to "out run" the fire and its harmful effects and more likely to be vulnerable to its effects than able-bodied individuals. Consequently, this group, because it is too capable to receive help all the way to safety, must be regarded as a vulnerable patient group in a fire emergency.

The prepared patients who require continued assistance [AR, for "assistance required"] present problems during a total evacuation effort. Each of these patients must be helped by an assistant to safety [AP, for "assistance provided"]. Whatever the form of removal assistance--being helped along by the arm or being pushed in a wheelchair--patients who receive continual assistance place a substantially greater demand on the exit channel than those who do not. Although a single wheelchair patient, for example, may be moved as fast as an able-bodied assistant can move, the assistant plus the wheelchair takes up more of the

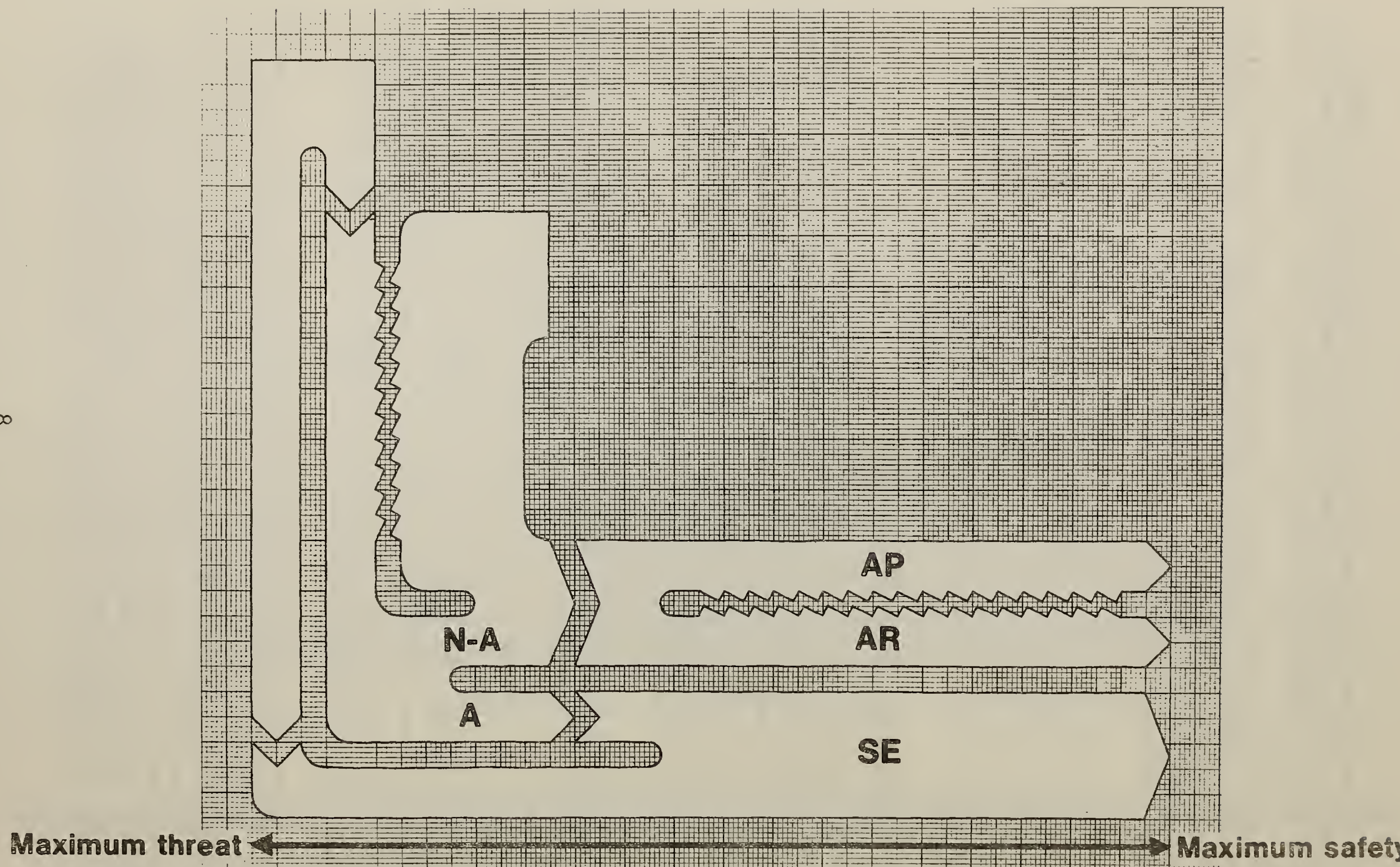

FIGURE 3: REMOVAL FROM THE THREATENED ZONE, WHERE (A) IS THE AMBULATORY STATUS OF PATIENTS AFTER PREPARATION; (N-A) IS THE NON-AMBULATORY STATUS OF PATIENTS AFTER PREPARATION; (SE) IS THE SELF-EVACUATING ACTION OF AMBULATORY PATIENTS; (AR) IS THE EVACUATION ASSISTANCE REQUIRED OR RECEIVED BY NON-AMBULATORY PATIENTS; AND (AP) IS THE EVACUATION ASSISTANCE PROVIDED BY TRAINED ASSISTANTS.

available space in the exit route than does a single fully ambulatory evacuee. The overall reduction in speed, increased demand for space, and decreased flexibility from attempting to move cumbersome objects through constricted channels can seriously disrupt the overall continuity of the outward flow. Substantial queuing can be expected to occur as temporary blockages develop while wheelchairs, for example, are guided around corners or through fire doors.

Although evacuation diminishes each patient's exposure to risk at the threatened end of the route, it also introduces risks of its own: injury enroute, or illness due to overall exposure at the safe end. These possible consequences will be treated as acceptable costs, given the benefits (e.g., survival) of efficient and effective evacuation. Nevertheless, given the elderly and debilitated status of occupants of nursing homes and health-care facilities, the relative magnitude of these costs (risks) is an open question.

1.4 SUPPLY OF PREPARATION MANPOWER

Evacuation assumes available preparation and evacuation manpower. The time spent covering the distance to get manpower where it is needed is critical to the success or failure of any evacuation effort. For many building fires, the required personnel probably will be initially located a considerable distance [d, for "distant point"] from the fire. Of course, if nurses or orderlies are in the immediate vicinity of the fire, their presence is likely to lead to earlier detection and a subsequent minimization of the threat. The initial supply of preparation manpower [IS, for "initial supply"] is shown in Figure 4. This activity must precede the initiation of the preparation process [PP].

The analysis of supplying preparation manpower requires new concepts. One of these new concepts is the "most threatened patient"--the individual who is most critically affected by the threat of flame, smoke, toxic fumes, or heat. Once the person is prepared and evacuated, another individual becomes the most threatened patient. If the threat is developing along more than one front (e.g. along two separate corridors), there will be a succession of most threatened patients for each fire front. The succession may not always be clear. Nevertheless, there will always be someone on each fire front who, by virtue of his or her proximity to the threat, is more threatened by it than the others.

A second concept is manpower distribution. This is a measure of where available assistants are relative to the location of the most threatened patients. This concept addresses the number of available assistants, their effective distance(s) from the most threatened patient(s), and the number of intervening opportunities occurring enroute. Intervening opportunities include calling the fire department, seeking more help, or closing doors to patient rooms. (The latter can significantly delay the delivery of preparation manpower to the most threatened patient.) The number of intervening opportunities generally will diminish as the fire develops. However, the level of uncertainty associated with the delivery of preparation and evacuation services may increase as the

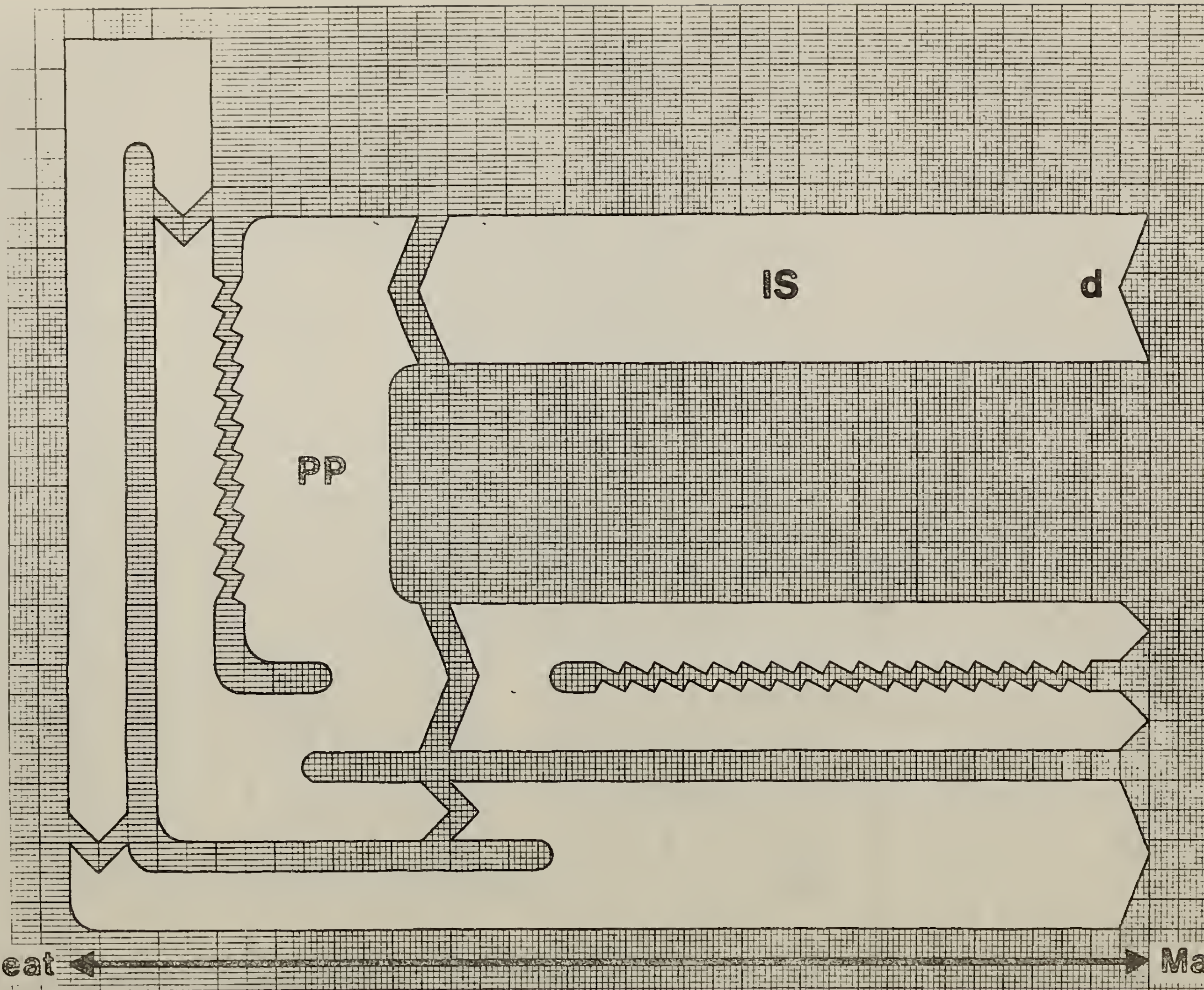

FIGURE 4: SUPPLY OF PREPARATION MANPOWER, WHERE (d) IS A 'DISTANT POINT' AT WHICH THE ASSISTANT IS INITIALLY LOCATED; (IS) IS THE INITIAL SUPPLY OF MANPOWER; AND (PP) IS THE PREPARATION PROVIDED BY TRAINED ASSISTANTS.

fire develops. That is, as smoke builds up, doors are closed and responsibilities are shared by more people, the determination of where patients are located, who has been evacuated, how much time is left, or what risks lie behind a closed door becomes more difficult, hence more uncertain.

Because of uncertainty, the manpower supply process is not the kind of task that can be easily conceptualized or easily performed in a prescribed manner. The evacuation process offers the assistant no vantage point from which to fully grasp the progress of the situation he is in. This makes the tenuous bond between the assistant and the patient pivotal to the success or failure of the entire evacuation process.

Because time is the key measure of performance, the idea of initial response time will be introduced to represent the interval between the decision to evacuate and the arrival of an assistant at the side of the most threatened patient. Thus, the helpers' response times for the succession of next most threatened patients can be determined. Since response times depend on the location of the assistants (e.g., staff) and patients at the time the decision to evacuate is made, it is possible that the actual response time of the first assistant might take a substantial portion of the required total time available to able-bodied occupants for evacuation within the hydraulic model.

1.5 RESUPPLY OF MANPOWER

With an infinite supply of preparation manpower, each assistant would have one patient to prepare and evacuate. However, in practice, the supply of preparation manpower is limited. Therefore, not one but more than one patient will have to be helped to evacuate by each assistant who is willing and able to return to the threatened end of the evacuation route. The resupply of manpower is illustrated in Figure 5. After escorting a dependent patient to safety [AP, for "assistance provided"], each assistant returns to prepare and remove other patients exposed to the continuing threat [RM, for "resupply manpower"]. One aspect of this process will be the opportunity for "rest and recovery" [R&R, for "rest and recovery"] at the safe end of the route. As the fire threats increase, this opportunity becomes more necessary. Fatigue and fire-related stressors can sap the endurance of the helpers. This, in turn, can crucially affect the rate at which manpower can be resupplied to patients requiring assistance. Thus, by coupling the resupply manpower rate [RM] with the initial supply of manpower [IS], an overall manpower supply rate [MS, for "manpower supply"] can be established. The initial response time plus the overall manpower supply rate provides an estimate of the overall level of preparation and evacuation service that can be provided in a given emergency situation.

If manpower is resupplied by assistants returning to the threatened end of the evacuation route, there is an "evacuation circuit" -- a two-way flow between a most threatened patient, a zone of safety or refuge, and the next most threatened patient. The length of this circuit is a function of the distance between threatened patients and the nearest

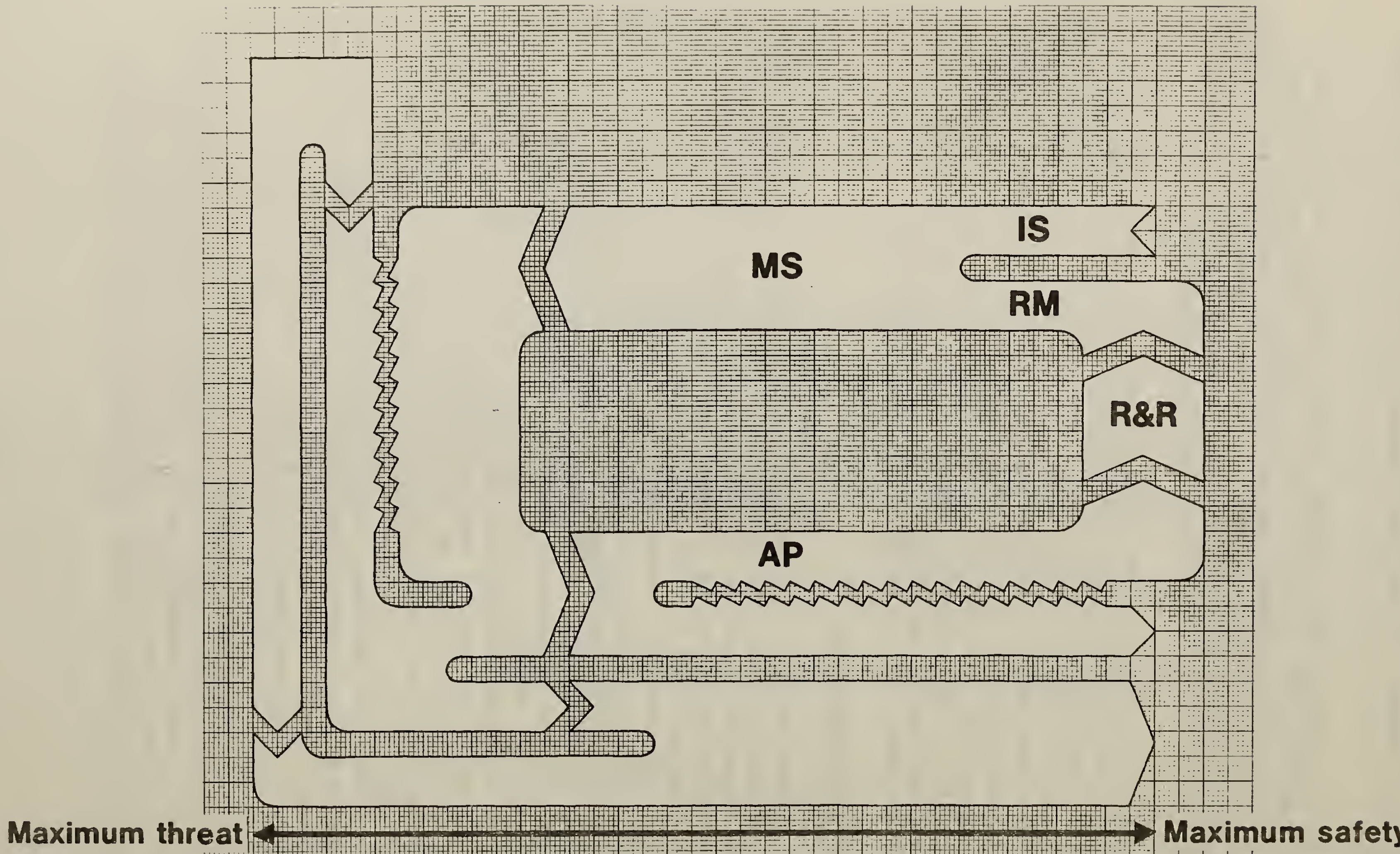

FIGURE 5: RESUPPLY OF MANPOWER, WHERE (AP) IS THE EVACUATION ASSISTANCE PROVIDED BY TRAINED ASSISTANTS; (RM) IS THE RESUPPLY OF MANPOWER; (R&R) IS THE REST AND RECOVERY REQUIRED TO OFFSET THE EFFECTS OF THE FIRE AND FATIGUE; (IS) IS THE INITIAL SUPPLY OF MANPOWER; AND (MS) IS THE TOTAL MANPOWER SUPPLY FOR PATIENT PREPARATION.

unobstructed exits. The length should diminish as more patients are evacuated. The time required to cover the evacuation circuit, including rest and recovery at the safe end, should determine the rate at which assistants can be resupplied to the next most threatened patients.

The concept of "counterflow" is introduced to describe assistants returning to help additional non-ambulatory patients. It will be important to determine whether the shuttling between the safe end and the threatened end of the route reduces the carrying capacity of the channel and if counterflow actually provides supplementary manpower when it is needed. This determination is important because efficient reuse of limited manpower plays a pivotal role in the success or failure of the evacuation effort and in the overall cost of that effort in terms of injuries and other losses.

1.6 MANPOWER ORGANIZATION

Five steps in patient evacuation have been covered: (a) the supply of qualified assistants, (b) patient preparation, (c) patient removal/evacuation, (d) brief rest and recovery of the assistant, and (e) the resupply of assistants. Unfortunately, the efficient execution of these operations will not result necessarily in the successful evacuation of large numbers of non-ambulatory patients. If there is limited supply of assistants and if too much effort is devoted to the first few patients, then less time will be available for other dependent patients. As the fire progresses, these conditions jeopardize the successful evacuation of these patients.

This situation can be alleviated somewhat if the supply of manpower increases as the fire develops. It is assumed that lowest numbers of assistants usually will be available at the beginning of the evacuation process and their numbers will increase as people, including additional staff and firemen, respond to the fire emergency. If this is the case, then initial preparation and evacuation efforts should be limited to the provision of a minimal, but sufficient, level of service to as many threatened patients as possible, leaving to newly arriving personnel the provision of the remainder of the assistance required by each evacuee.

What has been described is called "task differentiation." It is illustrated in Figure 6. The available supply of assistants [IS] devote their efforts to patient preparation [PP] and to providing partial assistance [PA] by removing patients from the immediate sources of threat. That is, prepared patients receive enough limited assistance [AR_1, for "partial assistance received"] in order to be evacuated to an intermediate point of refuge [i, for "intermediate"] which removes them for the immediate threats but leaves them for the time being less threatened but still in the threatened zone. The later supply of assistants concentrates on continuing the evacuation assistance [CA, for "continuation of assistance"] required to remove patients from the threatened zone [i] to safety [AR_2, for "continuation of assistance received"]. This differentiation of tasks allows the initial assistants to immediately

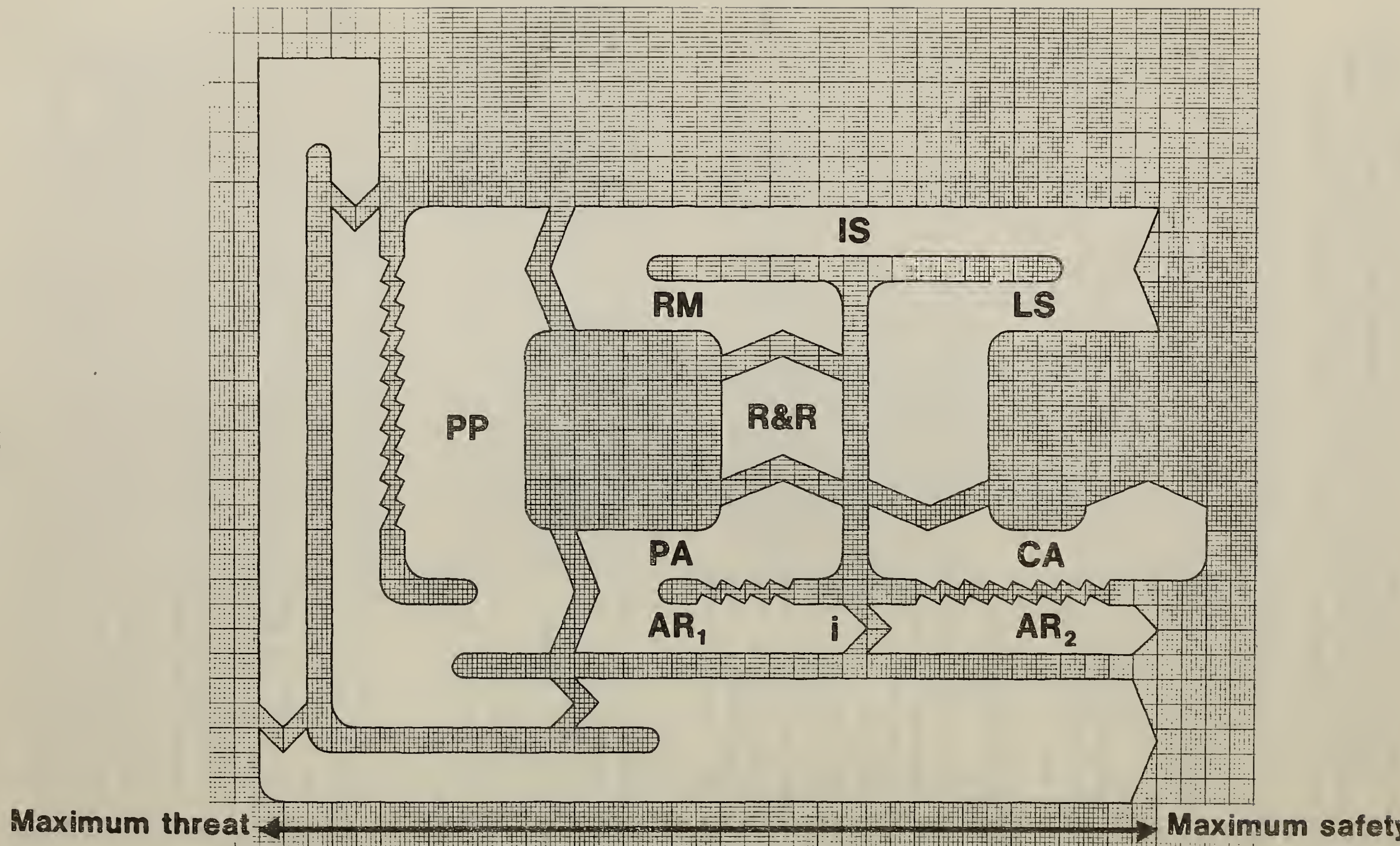

FIGURE 6: MANPOWER ORGANIZATION, WHERE (IS) IS THE INITIAL SUPPLY OF MANPOWER; (PP) IS THE PREPARATION PROVIDED BY TRAINED ASSISTANTS; (PA) IS THE PARTIAL ASSISTANCE GIVEN TO NON-AMBULATORY EVACUEES; (AR_1) IS THE PARTIAL ASSISTANCE RECEIVED BY THOSE EVACUEES; (i) IS AN 'INTERMEDIATE POINT' TO WHICH EVACUEES ARE FIRST MOVED; (LS) IS THE LATER SUPPLY OF MANPOWER; (CA) IS THE CONTINUATION OF ASSISTANCE GIVEN TO NON-AMBULATORY EVACUEES; (AR_2) IS THE CONTINUATION OF ASSISTANCE RECEIVED BY THOSE EVACUEES; (R&R) IS REST AND RECOVERY; AND (RM) IS THE RESUPPLY OF MANPOWER.

resupply manpower [RM] to prepare the next most threatened patients after a momentary opportunity for rest and recovery [R&R].

Task differentiation requires the provision of intermediate protection, like a closed fire door, at the intermediate holding position. The most effective way to provide intermediate protection is to use a patient room or some other enclosed area with its doors closed as a holding area.

There are advantages and disadvantages to task differentation. The advantages are: (1) service is delivered to more threatened patients; (2) the use of means of egress by assistants is reduced; (3) assistants who are familiar with the situation remain where that knowledge is most useful; and (4) it takes full advantage of the later arrival of more help.

The major disadvantage of task differentiation is there is greater exposure to risk by assistants who initially prepare and partially evacuate patients [AR] compared with helpers who primarily complete the evacuation of patients [AR_2]. To reduce the risks of overexposed assistants, it is recommended that they be allowed to occasionally accompany a highly vulnerable patient all the way to safety. However, managing such a rotation of personnel under emergency conditions--even if this involves trained staff--can be difficult. Difficulty will arise, for example, if there is no previously established "chain of authority" to facilitate the shifting of responsibilities among staff. Moreover, in the commotion of an actual evacuation, it is unlikely that a chain of authority will emerge.

There is another disadvantage of task differentiation. An established evacuation plan can run afoul when the services of persons who are unfamiliar with the plan are introduced into the evacuation process. Such persons would include visitors to the building of passers-by "off the street." Unless the role of these outsiders is anticipated, the efficacy of drills and plans in an actual emergency will be serious compromised.

Whether or not the proposed procedures can be successfully implemented under emergency conditions, more consideration must be given to how an evacuation is organized and how responsibilities are allocated so that the overall level of performance during a particular evacuation effort is optimized.

In sum, this chapter has presented the major factors involved in evacuating non-ambulatory patients during hospital and nursing home fires. Figure 7 summarizes the relations among all of these factors. Successful implementation of the complex procedures described in this chapter seems quite problematic under emergency conditions. Nevertheless, it appears that more consideration must be given to how an evacuation is organized and how responsibilities are allocated if the overall level of performance during particular evacuation effort is to be optimized.

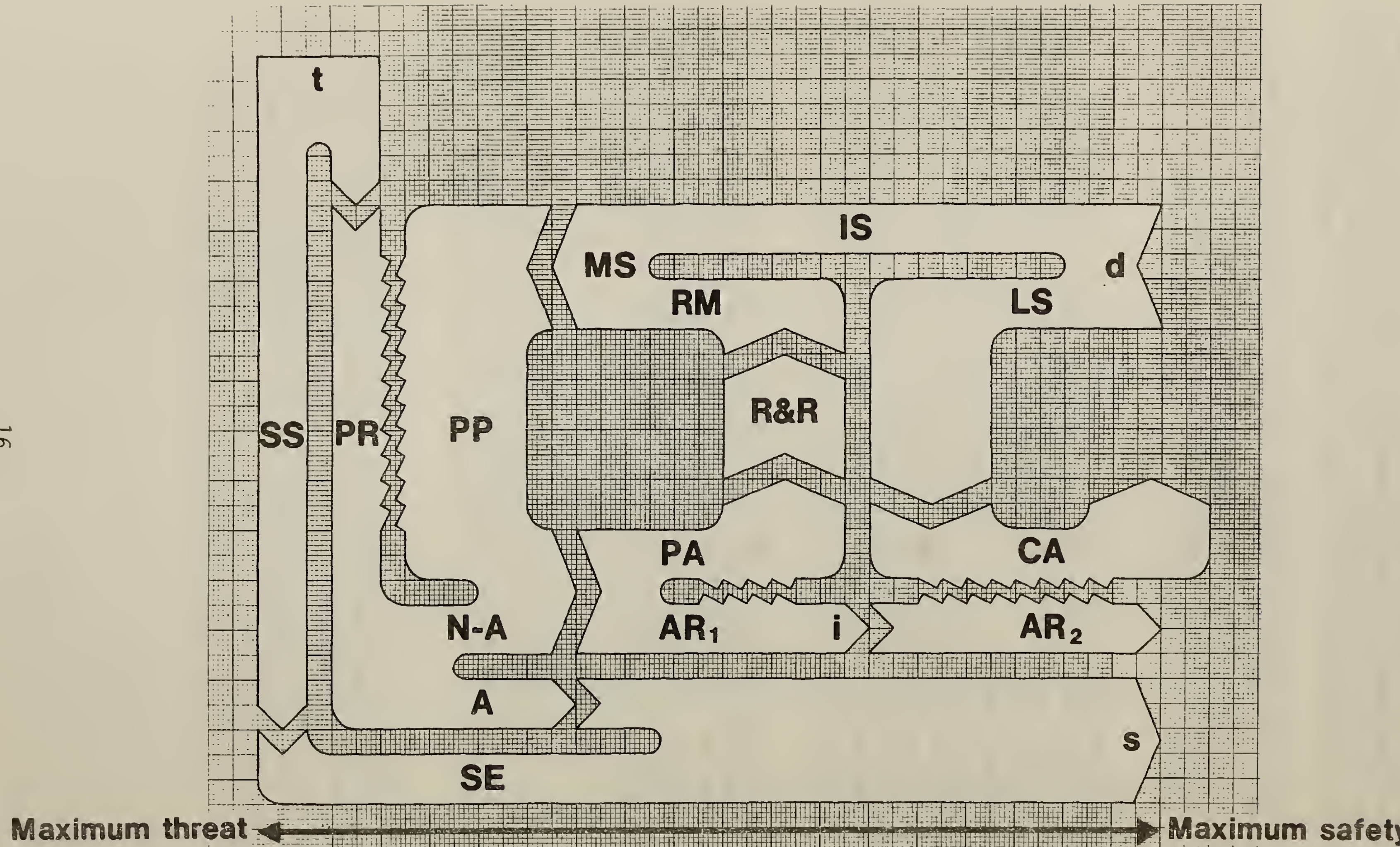

FIGURE 7: SUMMARY OF MAJOR FACTORS. SEE THE KEY FOR AN EXPLANATION OF THE SYMBOLS. THE SYMBOL (AP) DOES NOT APPEAR IN FIG. 7 BECAUSE IT HAS BEEN SUPERSEDED BY (CA) AND (PA).

2. THE EVACUATION PROCESS

In this chapter, the overall evacuation process described in Chapter 1 is reconceptualized into five sequential phases in order to provide a framework for assigning priorities to factors that can control the success or failure of the evacuation process. The five phases are (1) the manpower supply phase, (2) the patient preparation phase, (3) the patient removal phase, (4) the rest and recovery phase, and (5) the manpower resupply phase. The reconceptualization is not a model of an evacuation system. Rather, it suggests classes of variables which such a model must include and measures by which the effectiveness of evacuation systems might be evaluated.

Each phase is a set of activities. Collectively, the activities make a unified contribution to the evacuation of non-ambulatory patients from fires in health care facilities. It is assumed that the time period during which each phase makes a decisive contribution to the success or failure of the evacuation effort as a whole can be quite limited. Based on this assumption, the most critical portion of each phase is defined as the minimum elapsed time required to complete all activities necessary to permit the initiation of the next phase of the evacuation process. The most effective portion of each phase is defined as the total elapsed time required to assure that no patient's exposure to risk is increasing. This is the point at which the continuation of a given set of activities begins to assume a lower priority than initiating another set of activities. Obviously, the critical and effective portions of each phase of the evacuation process are both related to the development of the fire and the efficiency with which all evacuation tasks are performed.

This chapter will examine each phase of the evacuation process with respect to (1) behavioral and environmental factors that constrain or facilitate performance, and (2) the critical decisions or trade-offs involved. For each phase patient, building and staff factors are discussed.

(a) Patient Factors - The non-ambulatory status of a patient in a hospital or nursing home fire is the driving force behind any evacuation effort. Minimizing the threat to these occupants is the primary goal of both an evacuation effort and of improvements in staff training, fire protection, or building design that might facilitate the evacuation process.

(b) Building Factors - Ordinarily, a building provides relatively stable "opportunities" for human activity. However, in a fire situation the stability of these opportunities rapidly diminishes. Unlike activities, fires do not occur within buildings. Rather, a fire changes the building itself; it must be considered as a "progressive change in the conditions of occupancy" of a building. Activity is necessarily disrupted in a fire situation; you cannot always stay where you are and cannot easily go where you wish. What were once opportunities can become "obstacles" to escape or evacuation.

(c) Staff Factors - During a fire emergency, the staff and other assistants must capitalize on the remaining opportunities in order to evacuate as many threatened patients as possible.

(d) Staff Decisions - The decisions, trade-offs, and options exercised by the staff are the key determinants of the success or failure of an evacuation effort. Because of the significance of staff decisions, during each phase of the evacuation process, this factor is listed as a separate category.

For each phase, examples of each factor that should be considered in any further analysis of that phase are listed. The list of examples appears as Figures 8-12, one figure for each of the five phases.

2.1 MANPOWER SUPPLY PHASE

If a fire starts in a nursing home or health care facility with non-ambulatory patients, the need arises for persons to assist them during the evacuation process. The act of going to the aid of a non-ambulatory building occupant is the manpower supply phase of the evacuation process. It begins when the decision to commence the evacuation process first reaches a potential assistant, and continues as long as assistants continue to reach threatened patients.

The most critical portion of the manpower supply phase is the time between the decision to evacuate and the arrival of the first assistant(s) at the side of the most threatened patient(s). The most effective portion of this phase of the evacuation is the time between the decision to evacuate and the arrival of a sufficient number of assistants to evacuate all threatened persons without further loss of life or serious injury. This represents a point beyond which the arrival of additional manpower adds less and less value to the overall evacuation effort.

Figure 8 lists examples of patient, building, staff and staff decision factors to be considered in any further analyses of the manpower supply phase.

2.2 PATIENT PREPARATION PHASE

Once a decision to evacuate a portion of a building is made, a threatened occupant may complete certain incidental activities before starting toward an exit. For an alert, autonomous occupant this is called the "start-up" period--a time to put on a robe, gather personal

Figure 8. MANPOWER SUPPLY PHASE: Examples of Factors

In any further analysis of the manpower supply phase, the following factors must be considered:

Patient Factors:

- The number of dependent, non-ambulatory patients or other occupants of the fire zone who are directly exposed to the threats of flame, smoke, toxic fumes or heat.
- The degree of dependency of the threatened patient population in terms of the numbers of assistants and any special equipment that initially might be required to prepare them for evacuation.
- The locations of dependent patients with regard to their respective distances from effects of the fire, potential assistants, any special equipment that might be needed, and from an intermediate point of safety or the safe end.
- The degree to which a given patient's location, condition and exposure to risk are apparent to a potential assistant using sensory cues or physical signals.

Building Factors:

- The location of the fire; the rate, severity and direction of fire development; and the spread of smoke, toxic fumes or heat.
- Spatial relationships between patient rooms, corridors, points of entry, staff work stations and other service areas within or adjacent to the fire zone.
- The number and physical condition of potential routes of access to the most threatened patients -- through corridors, adjacent rooms, exterior windows, etc.
- Protective obstructions along the route(s) of access to the most threatened patients -- closed fire doors, operating sprinklers, wire glass, etc.
- The distances between the most direct route of access to the most threatened patients and devices required for performing intervening tasks enroute -- phones, pull-boxes, extinguishers, equipment storage, etc.
- The reduction in visibility and air quality and the distortion of orientation cues introduced by smoke, flame, sprinkler showers and closed doors.

Staff Factors:

- The number of staff assistants initially in or near the fire zone at the time the decision to evacuate patients is made.
- The locations of the available assistants with respect to the most threatened patients.
- The available assistants' familiarity with the facility (e.g., layout, location of special equipment, and the institutions's fire emergency procedures) and the patients.
- The speed with which the assistants are able to proceed toward the most threatened patients, including the time spent to perform intervening tasks enroute.
- The ability of the staff to anticipate the appearance of an actual fire emergency and to evaluate fire threat development.
- The establishment and use of recognized and accepted chains of command.

Staff Decisions:

(After learning of a decision to evacuate patients):

- Whether to begin immediately to evacuate patients or to send an alarm, confirm the existence of the fire, fight the fire, conclude ongoing activity or flee.
- Whether to proceed directly to the fire zone or to perform intervening tasks enroute--closing doors to patient rooms, awakening other patients, sending an alarm, etc.
- Whether to proceed to the fire zone first or to gather special equipment along the way -- wheelchairs, stretchers, oxygen masks, etc.
- Which route should be taken to which point on the fire front (a function of one's past experience in using different parts of the facility and of one's perception of the location and severity of the fire).
- Who are the most threatened patients and where should one look for them.
- Whether or not to enter spaces that are filled with smoke or to open closed doors encountered near the point of origin.
- Whether or not any locations are beyond searching or any patients are beyond saving.

belongings, or the like. For most pre-evacuation tasks, their objective benefits may be less than their potential cost in terms of increased exposure to fire threats.

The task of either protecting the patient from the immediate effects of the fire or getting them ready to be evacuated from the threatened zone is the patient preparation phase of the evacuation process.[4] The most critical portion of the patient preparation phase is the time between the arrival of the first assistant(s) and the completion of the preparation tasks for the most threatened patient(s). The most effective portion begins with the arrival of the first assistant(s) and continues until all occupants whose safety is dependent upon protection or removal have been prepared for movement. This is the point at which the demand to remove prepared patients is greater than the demand to prepare additional patients. Whatever the difficulty in establishing the sufficiency of manpower during an actual evacuation, the actual utility of allocating limited manpower to preparing marginally threatened patients will be central to understanding the success or failure of the evacuation process.

Figure 9 lists examples of patient, building, staff and staff decision factors to be considered in any further analysis of the patient preparation phase.

2.3 PATIENT REMOVAL PHASE

Only after a dependent patient has been fully prepared for movement can the actual act of removing them from the threatened zone be considered. Unlike the manpower supply and patient preparation phases, the patient removal phase may proceed in stages. For example, the most threatened patients may be evacuated to an intermediate zone which affords limited protection but decreases the threat to the patient. This characteristic of the patient removal phase makes it a difficult phase to explicate.

The most critical portion of this phase begins with the movement of the most threatened patient(s) away from the fire front and ends when those patients have been removed from the immediate threats of flame, smoke, toxic fumes or heat. The most effective portion begins with the movement of the most threatened patient(s) and continues until all occupants of the threatened zone have been either removed from the likely effects of the fire or protected from the fire threat by bringing that threat under control.

Figure 10 lists examples of patient, building, staff and staff decision factors to be considered in any further analysis of the patient removal phase.

---

[4] This section emphasizes evacuation. However, another legitimate option is staying in one's room with the door closed (see Section 5.3.1).

Figure 9. PATIENT PREPARATION PHASE: Examples of Factors

In any further consideration of the patient preparation phase, the following factors must be considered.

Patient Factors:

- Requirements for sustained mechanical life support or therapy (e.g., intravenous blood, medication, heart monitors).
- Requirements for and the availability of life-support, transport and prosthetic equipment to enable sustained movement with or without assistance.
- Susceptibility to a serious deterioration in medical condition due to sudden changes in environment or movement (e.g., post operative shock, pneumonia).
- Awareness of the nature of the emergency and ability to cooperate with an assistant in the preparation process (a function of mental alertness, senility, sedation, medication, etc.).

Building Factors:

- The availability of an adequate workspace that is free from the immediate effects of the fire and from the congestion caused by the evacuation process.
- The effects of smoke, toxic fumes and heat on visibility and air quality.

Staff Factors:

- Proficiency in performing all required preparation tasks properly and efficiently.
- Personal characteristics required to perform tasks without strain or injury to the staff member.
- Cumulative effects of pre-emergency workload on alertness, endurance and ability to perform under stress during an emergency.
- Effects of evacuation tasks on energy expenditure and fatigue.
- The effects of personal and social characteristics (e.g., fear, disorientation, guilt, compassion or disdain for certain patients) on attitudes and motivation during a fire emergency.

Staff Decisions:

(After arriving at the side of the most threatened patient):

- Whether to prepare a patient for removal or to attempt to protect them in place.
- Whether or not to disconnect a patient's life-support systems -- intravenous nutrition or blood supplies, catheters, heat monitors, oxygen, etc.
- Whether to prepare a patient to be evacuated by an assistant or to move on his or her own.
- Whether or not to use a bed, wheelchair, stretcher or other device to transport the patient (a function of estimated manueverability, channel capacity, manpower availability and energy expenditure required).
- Whether or not to salvage any of the patient's personal property.

Figure 10. PATIENT REMOVAL PHASE: Examples of Factors

In any further consideration of the patient removal phase, the following factors must be considered:

Patient Factors:

- Mobility status of prepared patients in terms of the manpower or equipment needed to sustain movement (a function of weight, stature, medical condition, cooperation, etc.).
- The locations of non-ambulatory patients with regard to their respective distances from the effects of the fire, places of safe refuge or exits.
- The maximum effective speed at which movement can be sustained on an unobstructed route, with or without an assistant.
- The effects of stamina, endurance and determination on the patient's need to pause to regain strength enroute to the exit or refuge zone.
- Total numbers of evacuees requiring removal at any given point in time.
- Excess demands for space within the exit channel resulting from the use of assistants and life-support, prosthetic or transport equipment.
- The patient's exposure to stressors or injuries.
- The impact of awareness, familiarity, confusion or fear on potential disorientation or resistance in the face of ambiguous cues and strange circumstances.

Building Factors:

- Spatial relationships between patient rooms, treatment or activity areas, corridors, refuge zones and unobstructed points of egress, within or adjacent to the fire zone.
- The number and condition of potential egress routes -- through corridors, adjacent rooms, stairways, exterior windows, etc.
- The capacity of the egress route(s) with regard to the spatial demands of evacuees accompanied by assistants or encumbered with equipment.
- Obstructions to clear passage caused by equipment parked or temporarily stored within the egress route -- wheelchairs, food carts, crash carts, cleaning equipment, etc.
- Architectural barriers and excessive demands on human energy along the egress route -- excessively slip-resistant or slippery surfaces, heavy doors, ramps, stairs, narrow passageways, corners, etc.
- Height of the fire floor above ground level.
- The location of the fire within the fire floor.
- The rate and direction of fire development and the spread of smoke, toxic fumes or heat.
- The reduction of visibility and air quality and the distortion of orientation cues introduced by the effects of the fire.
- Choice points among alternative routes one encounters.
- Reduced route options and distorted orientation cues introduced by system failures -- power cut off, blocked exits, fire damage, etc.

Staff Factors:

- The number of staff assistants within the fire zone at the time removal begins.
- The actual and perceived proximity to the fire zone of additional assistants at the time removal begins.
- Familiarity with the physical layout of the facility, the location of primary and alternative exit routes, the locations of intermediate refuge zones, the spatial habits of the patients, the proper operation of transport equipment, and the institution's fire emergency procedures.
- The speed with which assistants are able to move evacuees away from the fire or its threatening effects, including time spent performing incidental tasks enroute.
- Human energy expenditure and fatigue resulting from the magnitude of the removal effort (in terms of the numbers of evacuees and distance) and from the specific techniques used to transport dependent patients.
- Asphyxiation or injury resulting from exposure to flame, smoke, toxic fumes or heat.

- The degree to which experience and training has anticipated the appearance of an actual fire emergency and increased the assistant's ability to interpret cues to the nature of threat development.

- The implementation of lines of authority and communication with regard to the allocation and coordination of assistants to priority tasks (task differentiation), the validity of information about the progress of the fire and the evacuation effort, and the separation of conflicting activities like firefighting and patient removal.

Staff Decisions

(Once the most threatened patient(s) have been prepared for removal):

- Whether to move the prepared patient all the way to a safe zone, to remove them from immediate threats only, or to prepare other patients (a function of estimated manpower availability and the immediacy of the risk to the various patients).

- Whether to assist partially ambulatory patients or to let them try to make it on their own.

- How many assistants to allocate to each non-ambulatory evacuee.

- Which route will most efficiently lead to a protected exit or refuge zone (a function of the estimated location and progress of the fire and past experience in using different parts of the facility).

- Whether to proceed directly to an exit or to perform intermediate tasks enroute -- closing doors, alerting other patients, assisting other patients or assistants, etc.

- Whether to stay with a dependent patient in the face of adversity or to abandon and sacrifice them.

2.4 REST AND RECOVERY PHASE

Energy expenditure and the effects of stress can be expected to reduce the ability of assistants to perform at peak efficiency over time. Suspending the evacuation tasks long enough to regain their ability is the rest and recovery phase of the evacuation process. Unlike the other phases, which are continuous or proceed in stages, the rest and recovery phase is intermittent--it is a series of brief episodes which might increase in frequency and duration as the evacuation continues.

The most critical and effective portions of this phase are linked to the progress of the preparation, removal, and resupply phases. The most critical portion begins when the first assistant stops to service his or her own needs, rather than those of a dependent patient. It ends either when the most threatened patients are removed from immediate danger or when enough additional assistants are available to assure their successful removal. With abundant manpower, there may be no rest and recovery phase if all threatened patients can be serviced before any assistant is overtaxed. With limited manpower, the need for rest and recovery may preempt the evacuation process with a resulting loss of life or serious injury to patients. Moreover, an assistant who refuses rest and recovery may become exhausted, injured or killed. Rest and recovery, then, is a necessity. The issue is whether the frequency and duration of rest and recovery episodes can be minimized by each assistant, without jeopardizing him or her, until the most threatened patients are out of immediate danger or until there is enough manpower available to aid non-ambulatory patients.

The most effective portion of this phase ends when all dependent occupants of the threatened zone have been or are assured of being sufficiently removed or protected from the fire to eliminate the likelihood of further injury or loss of life. This means that it is most effective when the frequency and duration of rest and recovery activities are such that they are minimally disruptive to the most effective portions of the other phases of the evacuation process.

Figure 11 lists examples of patient, building, staff and staff decision factors to be considered in any further analysis of the rest and recovery phase.

2.5 MANPOWER RESUPPLY PHASE

The need to recycle the manpower available to perform evacuation tasks is directly related to the limitations on the intial supply of preparation manpower. The more people available to assist in the evacuation process, the less need there is for any of them to enter the fire zone more than once. Under ideal manpower conditions there would be no need for a resupply phase. With a limited initial supply of manpower, the manpower resupply phase becomes necessary.

The most critical portion of this phase begins when the first assistant reenters the threatened zone and ends when sufficient manpower is at the

Figure 11. REST AND RECOVERY PHASE: Examples of Factors

In any detailed consideration of the rest and recovery phase, the following factors must be considered:

Patient Factors:

- The combined effects of the initial distances from protected exits or refuge zones, body weight, stature, levels of cooperation, medical condition and special equipment needs on the workload handled by staff assistance.

  Note that the asphyxiation, injury or exhaustion of a patient due to excessive energy expenditure, traumatic episodes, or exposure to the stressful effects of the fire during the preparation or removal phases are not "factors" in the evacuation process, but rather indications of its partial failure.

Building Factors:

- Spatial relationships between the "threatened end" and the "safe end" of the evacaution circuit and any other points of safe refuge within or near the fire zone.
- The number and condition of alternative routes between the area of fire involvement and refuge zones.
- The amount of space, level of protection, and supply of oxygen or fresh air available in the refuge zones.
- The combined effects of the intensity and distribution of flame, smoke, toxic fumes and heat, within or near the fire zone.
- The cumulative effects of the energy demands of the evacuation circuit -- stairs, ramps, long distances, heavy doors, excessively slip-resistant or slippery surfaces, etc.

Staff Factors:

- Smoke inhalation, injury, exhaustion due to excessive energy expenditure, trauma, or exposure to thermal or toxic stressors during the supply, preparation or removal phases.
- The cumulative effects of the allocation of individual workloads in terms of the rates of energy expenditure and the duration of exposures to the direct effects of the fire.
- The cumulative effects of the specific patient preparation and transport techniques used with respect to total energy expenditure and fatigue.
- Proper utilization of auxiliary breathing apparatus -- oxygen masks, etc.
- The amount of manpower available to service the needs of the remaining threatened patients.
- The effect of individual respiratory, metabolic, cardiac, allergenic or psychological conditions on endurance levels.

Staff Decisions:

(After reaching safe refuge following exposure to the effects of the fire):

- Whether or not one has the ability to perform any of the additional preparation or removal tasks that are needed.
- Whether assistants' contribution to the evacuation effort will be greater if they pause to regain some of their strength or if they reenter the fire zone immediately (a function of the estimated ratio between the manpower that is available and the magnitude of the task ahead).
- Whether or not to give up the security of a safe refuge by exposing oneself to further risks in the fire zone.

side(s) of the most threatened patient(s) to assure their successful removal from the immediate effects of the fire. Similarly, the most effective portion of the manpower resupply phase begins when the first assistant reenters the threatened end and continues until enough assistants are engaged in the tasks required to remove or protect all non-ambulatory patients of the threatened zone from the likelihood of further injury or loss of life. Precautions may be necessary to assure that an oversupply of manpower does not interfere with the efficient conduct of evacuation tasks and that assistants do not unnecessarily expose themselves to risk by reentering the fire zone after their services are no longer needed or their ability to function effectively has been seriously impaired by their arduous activities.

Figure 12 lists examples of patient, building, staff and staff decision factors to be considered in any further analysis of the manpower resupply phase.

Figure 12. MANPOWER RESUPPLY PHASE: Examples of Factors

In any further consideration of the manpower resupply phase, the following factors must be considered:

Patient Factors:

- The number of dependent, non-ambulatory patients within the fire zone(s) who remain exposed to the threats of flame, smoke, toxic fumes or heat.

- The conspicuousness of each remaining patient's location and situation using visual, auditory, tactile or automated sensing methods.

- The apparent condition of those patients who remain -- beyond saving, in need of help, likely to get out on their own, etc.

- The locations of the remaining dependent patients with regard to their respective distances from the effects of the fire, firefighting activities, and assistants who are ready to return to the fire zone.

Building Factors:

- Spatial relationships between patient rooms, corridors, points of entry and exit, and zones of safe refuge, within or adjacent to the fire zone.

- The number and condition of the potential routes of access to the next most threatened patients-- clear, deteriorating, impassable, etc.

- The availability of intermediate protection or protective equipment along the evacuation circuit -- streams of water, closed doors, breathing apparatus, etc.

- The location of the fire.

- The effects of control systems on the development of the fire and the spread of its effects -- firefighting, sprinklers, venting, pressurization, etc.

- The effects of the intensity of flames, smoke, toxic fumes and heat on visibility and air quality within the fire zone.

Staff Factors:

- The amount of manpower available and able to service the needs of the remaining threatened patients.

- The rate at which additional assistants and firemen are responding to the fire zone.

- The condition of the assistants available to return to the fire zone (a function of the effects of prior workloads and the adequacy of the rest and recovery period).

- The effectiveness of lines of authority and communication in maintaining a valid "reading" of conditions within the fire zone; allocating manpower to the appropriate high priority preparation and removal tasks (task differentiation); and coordinating the concurrent activities associated with evacuation, firefighting, and recovery or first aid.

- The psychological impact of the immediately preceding experiences within the fire zone on an assistant's willingness to return.

Staff Decisions:

(After determining that they have the ability to reenter the fire zone):

- Whether or not any further evacuations are necessary (a function of the estimated progress of the fire).

- Whether or not additional assistance will be needed to complete the necessary evacuations (a function of the estimated manpower supply and patient demand).

- Which route should be taken to the next most threatened patients (a function of prior experience in the fire zone).

- Which are the next most threatened patients (a function of knowing who has been removed and who hasn't).

- Whether additional risks are greater or less than the chances of success.

- Whether or not one might be held personally accountable for any of the successes or failures of the total evacuation effort.

3. EVACUATION AS A SYSTEM

This chapter addresses the possible relationships among the five phases presented in Chapter 2. These five phases identify and classify the activities for which any model of the evacuation process must account. Building on certain patterns among the patient, building and staff factors which reoccur throughout Chapter 2, this chapter elaborates these patterns as "first approximations" of the functional relationships that will be required to link the five phases of the evacuation process together into a total evacuation system. No such models of evacuation systems currently exist and such a model will <u>not</u> be developed in this chapter. Rather, this chapter will only suggest some classes of variables which such a model must include and some of the measures by which the effectiveness of evacuation systems might be evaluated.

One of the reasons for not carrying the model building process further at this time is that the proper basis for interrelating the five phases is not clear. Possible relationships between the five phases of the evacuation process are largely a function of the point of view from which the process is analyzed. For example, from the perspective of the individual patient, the issue is simply one of evacuating the patient fast enough or protecting him or her well enough to avoid death or injury. Thus manpower supply, patient preparation and patient removal can be treated as discrete tasks, performed serially on a patient-by-patient basis, and measured against a continuous time function. However, looking at the patient population of the fire zone as a whole, the issue becomes one of assuring that services are delivered in direct proportion to each patient's exposure to the effects of the fire. This would mean that no patient's immediate needs would remain unmet while less threatened patients were being helped. Here there is less concern for the sequence of discrete phases and more concern for decisionmaking and task differentiation within the preparation and removal phases.

If the analysis centers on the building rather than on the patient, the central concern shifts to the maximum utilization of the exit channel that can be sustained without queuing. From this point of view, the restrictions that channel width and distance place on the manpower supply and patient removal phases are the most critical.

Finally, from the individual assistant's point of view, the major concern is to minimize expenditure of energy and exposure to stress during the preparation and removal phases and to maximize the opportunity for rest and recovery whenever necessary. This is in contrast to a view which considers the group of assistants as an integrated team. Here the emphasis is on the maximum amount of work done per man-minute. This emphasis is contingent on managing the flow of information and manpower between the preparation, removal and resupply phases of the evacuation process.

Since there is too little data to support the assumptions of any of the viewpoints, one cannot determine how the five phases should be interrelated in order to best represent the evacuation process as a single system. The development of a definitive model, then, will have to await further research and post-incident investigation (see Chapter 5).

3.1 RELATIONSHIPS AMONG THE FIVE PHASES OF THE SYSTEM

From the various patient, building, and staff factors that were linked to the evacuation process in Chapter 2, certain patterns emerge. In an attempt to simplify this complex catalog of variables and to abstract their essential features, five system parameters are presented as a starting point for the modeling of evacuation systems for non-ambulatory patients in health care facilities.

3.1.1 Fire Development

Understanding the process of fire development is a precondition for the development of a capability for designing or evaluating an evacuation system that is responsive to the needs of non-ambulatory health care patients. Of greatest concern are the changes in the conditions of occupancy as a fire spreads under various material (fuel) and architectural (layout) conditions. In addition to the toxic and thermal effects of the fire, the effects of fire and its products on visibility and on orientation cues within the building are of concern.

3.1.2 Weighted Mobility Status

The speed with which dependent patients and staff assistants can move on their own or as pairs is critical. Among the important aspects of mobility status are the patient's psychomotor skills, the encumbering effects of life support and prosthetic equipment, and the patient's ability to cooperate. A goal of modeling evacuation systems should be measuring dependencies and encumbrances in order to assign weights to the mobility characteristics of non-ambulatory patients and their assistants as ratios of the mobility characteristics in independent, ambulatory populations.

3.1.3 Spatial Distribution

The respective locations of dependent patients and prospective staff assistants at the time the decision to evacuate is made, and the layout, design and conditions of the routes that link them to each other, to rooms, and to protected exits or refuge zones, are critical to the performance of an evacuation system. By describing the functions of the institution, the training of the staff, and the plans for evacuation in terms of the spatial behavior of those who require and provide assistance, there will be a basis for deriving travel times from distances under normal and emergency conditions. With an ability to calculate effective travel times and weighted channel capacities, critical performance factors like queuing can be explicitly measured (weighted channel demand minus weighted channel capacity). This framework also permits the explication of other factors that are amenable to interpretation as functions of time.

3.1.4 Task Proficiency

The ability of assistants to perform tasks and to operate equipment effectively (in terms of service to dependent patients) and efficiently (in terms of expenditures of their own resources) contribute to successful or unsuccessful performance of an evacuation system. The total amount of staff energy and time that must be expended on activities and tasks for their proper execution is of particular concern. In effect, determining the trade-offs between the amount of work done and the ability to do additional work is central to understanding staff performance during the evacuation process.

3.1.5 Manpower Organization

How reliable information about the fire, the patients, and the progress of the evacuation is delivered to the points at which critical decisions are made during an evacuation will have to be made clear. Of central importance are the ways in which information becomes available to and is corroborated by those making decisions and the ways in which those decisions are subsequently translated into courses of action within or near the fire zone. Thus, issues like chains of authority, manpower supply (especially undermanning and overmanning) and standardized signal systems must be considered because these influence the establishment of priorities, the division of responsibilities (task differentiation), and the allocation of manpower. An explicit formulation of the communication processes should account for the major sources of judgmental error during evacuations.

3.2 SYSTEM PERFORMANCE MEASURES

Once the full implications of the five system parameters in Section 3.1 have been clarified, we can begin to post measures of total system performance. One such measure might be a "removal rate": the rate at which dependent patients can be removed from a fire zone without queue formation enroute. It would be measured in linear feet per minute from the habitable point closest to the origin of the fire. This measure would aggregate supply and replacement rates of assistants, the preparation times of most threatened patients, and the rates at which prepared patients can be removed from the threatened end of the evacuation route.

Another recommended measure would be a "margin of sufficiency": the removal rate minus the rate of fire development. It, too, would be measured as a linear progression from the point of ignition. This variation of Caravaty and Haviland's (1967) treatment of critical times and reaction times would provide a measure of evacuation system performance at the patient/fire interface. When the margin of sufficiency equals zero, evacuation is proceeding at the same pace as the fire and the effort is just barely sufficient to avoid additional casualties. When it is negative, the effects of the fire are spreading faster than patients are being evacuated and further death or injury would be expected to result. When the margin of sufficiency is positive, the removal rate exceeds the rate of fire development. The widening margin at the patient/fire interface permits other activities, like firefighting, to occur without interfering with the evacuation effort.

In conclusion, the adoption of the proposed measures cannot be fully supported by the currently available data. Nevertheless, they illustrate the types of measures that have to be developed if the special problems of non-ambulatory evacuees are to be studied and solved. System performance measures will require evacuation system models that can be tested against performance in actual emergency evacuations.

4. GUIDELINES FOR THE DESIGN AND ASSESSMENT OF EVACUATION SYSTEMS

The systematic analysis of the evacuation process is ultimately a matter of measurement of initial conditions and of performance. Measures of initial conditions such as patient mobility and the physical layout of the facility must be supplemented with measures of predictable changes in initial conditions as the fire presents new obstacles to or reduced opportunities for efficient performance. Measures of performance would include how assistants can be expected to carry out evacuation tasks during a fire. The best approximations of these initial conditions and performance factors that can be supported by the available evidence appear below as guidelines for the design and assessment of evacuation systems. Recommendations for additional research on the patient, staff, and building factors in the evacuation process are in Chapter 5.

4.1 DESIGN CONDITIONS

Although the circumstances involved in the origin, progress and outcome of a particular fire generally can be reconstructed with some accuracy, it is quite difficult to predict these circumstances. Yet predicting the nature of a future fire is a prerequisite for planning emergency training programs or drills, for designing an adequate fire evacuation system, or for certifying the reliability of either. That is, a model of a typical emergency situation must provide performance requirements for evaluating the design of an evacuation system, including critical initial conditions imposed by the fire and the ideal performance conditions of an evacuation team.

The idealized set of emergency conditions provided by the model to evaluate the performance of an evacuation system should help determine the best results that can be expected if every component of the evacuation system functions properly. In the case of hospital, nursing home or rooming house fires, however, little systematic data is available to pinpoint these performance requirements. However, based on Lerup's (1975) analysis of ten nursing home fires and other reports (Caravaty and Haviland, 1967; Ferguson, 1975; Lefer, 1976), the following design conditions are reasonable first approximations.

4.1.1 Critical Initial Conditions

Critical initial conditions are the typical or likely state of the patients, building and staff at the time the decision to evacuate is made. Both the mobility status of the patients and the physical layout of the building are facility-specific initial conditions. This means that patient mobility is a function of the facility's specific custodial or therapeutic mission and the effective range of wheelchairs or rolling beds is a function of maneuverability restrictions imposed by specific corners, door jambs, and building design features. Seven examples of initial conditions that are more generally applicable follow.[5]

4.1.1.1

The degree of exposure to risk of ambulatory and non-ambulatory occupants of a building during a fire is a function of their initial proximity to and their remaining near the fire or its negative effects rather than of their mobility or dependency status.

4.1.1.2

The maximally dependent patients may either be (a) randomly distributed throughout the sleeping, treatment, and circulation areas of the facility or (b) concentrated in a relatively compact treatment, dining, or assembly area of the facility. These are the two most extreme cases. The randomly distributed condition, (a), would be typical both of therapeutic and custodial situations throughout the day and of late evening and overnight periods when most patients would be asleep in their rooms. This condition places great emphasis on travel time and exposure during the supply and removal phases. The concentrated condition, (b), would be typical of specialized intensive care facilities and of dining or worship periods in a more diversified unit. This condition, (b), places the greatest effort on the availability of preparation manpower and congestion or queuing. Both conditions must be considered in the design and evaluation of an evacuation system.

4.1.1.3

It is assumed that there will be few staff assistants within a threatened zone initially, but their numbers will increase over time. The concern, here, is the actual (in contrast to assigned) number of assistants present. The rate of increase in the manpower supply is largely facility-specific and depends on the staffing of adjacent zones within the facility, the location of the facility with respect to other facilities, such as fire departments, and the nature of the road system that connects the threatened facility with other facilities.

4.1.1.4

The available staff is likely to be concentrated near the nursing station or other center of operations like a pharmacy or laboratory. Even granting this assumption, the design of an evacuation system should be based on initial travel distances that are equal to or greater than the distance from the nursing station to the point of origin of the fire.

---

[5] An initial condition can be generally applicable and still have its specific form of application determined by the facility or patient population to which it is being applied.

4.1.1.5

The origin of the fire may be (a) near the most distant patient bed from the nursing station or (b) at the location of a known fire hazard. In the distant condition, (a), a gradually developing fire of accidental or incendiary origin is more likely to grow out of control in a location that is removed from frequent staff surveillance from the nursing station. These fires force consideration of issues of travel time, fire development on more than one front, and blocked access to patients and/or exits. This would be a typical location for a fire late at night. The known hazard condition, (b), includes laundry and trash chutes; open flames used in kitchens or laboratories, volatile substances used in treatment rooms or operating theaters and poorly ventilated electrical or thermal equipment as in data processing or mechanical equipment areas. Such fires are likely to occur much closer to the center of a health care facility and to develop more rapidly than fires originating in patient areas. Fires toward the center of the facility are likely to be detected because they are likely to be in areas where there is staff surveillance. If undetected, however, then because of their location and rapid growth, these fires can grow into major fire emergencies. Such fires force consideration of issues like asphyxiation of staff assistants, blocked egress routes, and major congestion and queuing problems.

4.1.1.6

Although the details of fire growth are beyond the scope of this report, it is essential that any evacuation or protection plan must be predicated on increasing levels of stress and diminishing options for escape as time passes.

4.1.1.7

A critical portion of the evacuation process will have to be accomplished within the first few minutes after the decision to evacuate has been made because visibility will decrease rapidly with the growth of a fire. Although this is related to Section 4.1.1.6, it is being considered separately because vision plays a central role in direction finding, task performance, and decisionmaking under highly uncertain conditions. Put differently, the opportunities for efficient task performance will decrease as the fire progresses and visibility decreases.

4.1.2 Ideal Performance Conditions

The ideal performance conditions can be facility-general or facility-specific. In either case, the concern is with the most effective use of manpower and equipment in an actual fire emergency evacuation. Staff size and staff capability are facility-specific. For example, more assistants with a higher level of professional training would be expected to be on duty in the intensive-care unit of a general hospital than in a custodial nursing home. For either type of facility, however, staff preparation for conducting a fire emergency evacuation will be a function of the specific facility's administrative policies. Seven examples of performance conditions that can be assumed to be generally applicable to hospital or nursing home emergencies follow.

4.1.2.1

Total evacuation of the threatened zone will be required. Any evaluation of an evacuation performance must consider the removal of all dependent patients from a threatened zone as a minimal objective.

4.1.2.2

Dependent patients will be assisted in the order of their exposure to the threats of flame, smoke, heat, or toxic fumes. During the earliest and most critical portions of the evacuation process, the sequential servicing of "next most threatened patients" appears to be essential to the success of the total effort. At later stages, when the immediacy of the threat diminishes or the degrees of exposure of the unserviced dependent patients approach equality, the order in which the remaining patients are serviced will probably have less bearing upon the final outcome.

4.1.2.3

Movement speeds during the evacuation process will either be at a fast walk or at a slow walk. The fast walk condition would be typical of assistants (including firemen) as they first respond to the emergency during the manpower supply phase and as they move from one patient to another during the manpower resupply phase. It also applies to fully ambulatory patients escaping without assistance. A speed of approximately 7.00 f.p.s. (2.18 m.p.s) is the maximum that can be assumed for level walking under these conditions. This speed is based on the assumption that there is no intervening activity like closing doors to patient rooms (Murray, 1966). If intervening activity is considered, the slow walk condition would apply. Adapting Fruin's (1971) 3:1 ratio between horizontal speeds on the level and on stairs, the horizontal component of a fast walk down stairs would be approximately 2.33 f.p.s. (0.70 m.p.s.). The rates for ascent would be approximately 35 percent slower. It is assumed that people will not run at any point in the evacuation process.

The slow walk condition would be typical for unassisted elderly or handicapped evacuees, all assisted patients and their accompanying assistant(s) during the patient removal phase, and all assistants engaged in moving equipment, searching for victims or providing intermediate protection by closing doors.

From unpublished preliminary data on the movement speeds of unassisted elderly and handicapped person using various prosthetic devices (E. Steinfeld, personal communication, 1976; J. Templer, personal communication, 1976), it appears that a movement speed in the range of 2.50 f.p.s. (0.75 m.p.s.) would be a reasonable assumption for slow walking on an unobstructed level route. In general, the group that moves the slowest are persons who use prosthetic walkers. However Steinfeld reports one wheelchair user who moved at 0.56 f.p.s. (0.17 m.p.s.) and others who were only slightly faster. These people would require assistance. In the absence of relevant data, it is assumed that assisted evacuees would progress at approximately the same speed. Similarly, accepting Fruin's 3:1 ratio, the horizontal component of the slow walk down stairs would be approximately 0.83 f.p.s. (0.25 m.p.s) with ascent slightly slower. All of these rates of movement (fast versus slow and level versus stair) are substantially in accord with the unpublished preliminary results of a simulated evacuation conducted by the Fire Research Station in England (Appleton and Quiggin, 1976). In addition, Jin (1976), Watanabe, Nayucki, and Torizaki (1973) and Tashida (1975) have shown that movement speeds are further reduced in proportion to the density of smoke.

4.1.2.4

All dependent patients within the threatened zone will require some preparation assistance. While some patients will be less dependent than others, it should be assumed that all will need at least to be awakened or reoriented toward the nearest exit. In critical situations, preparation can involve, for example, switching the patient from a fixed to a portable life support system or transferring the patient from a bed to a stretcher. The time involved in preparation is critical to the success of the overall evacuation effort.

According to unpublished preliminary data, the mean and modal amount of time required for relatively extensive preparation during a simulated evacuation was 120 man-seconds (I. Appleton, personal communication, 1976). Recognizing that patients may require considerably more or less preparation than was called for in that simulation, and with no other data available, 120 man-seconds will be taken as a resonable approximation of the time which should be allowed for preparation.

4.1.2.5

Dependent patients will be fairly cooperative with assistants during the preparation and removal phases of the evacuation process. Seemingly counterproductive patient behavior that has been reported can be attributed to the highly unfamiliar and uncertain circumstances of fire emergencies.

4.1.2.6

Assuming a relatively high level of professional commitment to the wellbeing of their charges, trained assistants will perform preparation and removal tasks to their endurance limits. Their efficiency of task performance can diminish over time due to physical and mental fatigue alone or because their exposure to flame, smoke, toxic fumes or heat exceeds their tolerance level. The major exceptions should occur when an assistant is unfamiliar with his environment and unaccustomed to his role or is professionally uncommitted and feels no sense of obligation. The former case must be considered in light of Haber's (1977) findings of annual staff turnover rates in excess of 50 percent in nursing homes. The latter case could apply to visitors or spectators off the street who find themselves pressed into service.

Trained assistants generally will make correct decisions based on available information during the evacuation process. This assumption, like patient cooperation and efficient task performance, will not always be the case. Bickman (1977), for example, reports that assistants often tend to select egress routes which are more familiar rather than those which may be more direct. Nevertheless, the assumption of correct decisions which could provide an acceptable level of life safety in a critical fire emergency, like the assumption of well maintained facility with properly functioning equipment, should be part of one's evacuation system design.

In sum, given these fourteen general assumptions and the patient, building and staff characteristics of a given facility, it should be possible to make preliminary estimates of the time that would be required to perform a successful evacuation of dependent patients in an actual fire emergency if everything goes well. It also should be possible to estimate the effects of difficulties attributable to patients, building, and staff characteristics.

5. RECOMMENDED RESEARCH ON EVACUATION SYSTEMS: AN AGENDA

The review of critical intitial conditions and ideal performance conditions, in Chapter 4, demonstrates how little is currently known about the movement of non-ambulatory hospital and nursing home patients under emergency conditions. The assumptions in Chapter 4, at best, provide a very rough approximation of the conditions surrounding a likely emergency evacuation. They fall far short of the detailed understanding that is required to design or evaluate evacuation systems for the elderly and handicapped in a systematic manner.

There are at least two broad areas in which a concerted research effort is necessary in order to provide a basis for reliable design and policy decisions. One is research on spatial and mobility aspects of routine health care activities, that is, on initial conditions prevailing when a fire is discovered or a decision to evacuate is made. The other is research on actual performance levels under real emergency conditions in hospitals and nursing homes. A third, more narrowly defined, area also requiring research is intermediate protection and evacuation tradeoffs. Specific research topics for these three areas are discussed in Sections 5.1, 5.2, and 5.3, respectively.

5.1 INITIAL CONDITION MEASURES

This section focuses on quantifiable descriptors of the normal states of the patients, staff and building at key points throughout the daily routine. In order to develop a basis for determining the spatio-temporal relationships between potential fire victims and potential assistants, as those relationships are defined by the physical layout of the building and the location of the fire, further research is needed. Since these relationships will vary according to the nature of ongoing activities, specific attention must be paid to developing a framework that can accommodate the distinctions between a situation that might occur at night when all of the patients are asleep and one that might occur at noon when all are assembled with friends, visitors, and volunteers for lunch and relaxation. Only those research issues that bear directly upon the evacuation of non-ambulatory patients from health care facilities are included.

5.1.1 Mapping of Staff and Patient Routines Throughout the Daily Cycle

This issue refers to a spatio-temporal mapping of the characteristic patient, staff, and visitor activities throughout the day and night. A person's location is related to his or her ongoing activity. The distances between dependent patients and staff assistants are a function of their respective locations. The time required for the latter to come to the aide of the former is related to these distances. Therefore, it is essential to know who tends to do what, where, when, and with or for whom if accurate assumptions about patient demands and manpower availability are to enter into evacuation system design or assessment. Although not directed to evacuation, there are a substantial number of behavior mapping studies in health care facilities (Gump and James, 1970; Ittleson, Rivlin and Proshansky, 1970; LeCompte and Willems, 1970; Lippert, 1971 a,b,c; Srivastava and Good, 1968; Trites, et al., 1970). One study strongly indicated that the least competent nursing home patients tend to be assigned to rooms that are the farthest from the nursing station (Bader, Maxwell and Watson, 1972). Bader et al.'s findings have been confirmed by Haber (1977).

5.1.2 Modeling of the Spatial Organization of Health Care Facilities

This issue refers to a quantitative description of spatial relationships and communication networks between specifiable activity areas. Given the diversity of health care facility floor plans, a conceptual language is needed to describe the spatial organization of a building. This would be in contrast to the use of descriptors rooted in historical styles (Kirkbride, Nightingale, pavilion, etc.) or of symbolic labels (Y-shaped, high rise, noninstitutional, etc.). Without such a conceptual language, virtually all design and regulatory decisions dealing with occupant behavior in fire emergencies will be building-specific.

Also, what is needed is an objective format for incorporating alternate route structures, corridor loadings, channel widths, intervening opportunities and other attributes of connectedness, redundancy, extent and capacity into the description of a health care facility. A geometric typology of hospital layouts developed by Wehrli and Kapsch (1972) represents a preliminary step in this direction. To date, building-scale adaptations of location theory and diffusion models developed in economic geography and industrial engineering are few in number (Archea, 1974; Baer, 1974), but show some promise.

5.1.3 Studies of the Accessibility of Egress Routes

This issue refers to measures of the difficulties introduced by configurational obstacles along an exit route to the movement of special equipment and the handicapped. Research on the mobility of the elderly, people using wheelchairs and other prosthetic devices, and persons with acute motor disabilities (e.g., hemiplegia) is the basis for the latest revision of the ANSI A117.1 "Specifications for Making Buildings and Facilities Accessible to and Usable by Physically Handicapped People" (Steinfeld, 1977). Preliminary research has been initiated on bearing stretchers down stairs, through doors, and around tight corners by Johnson and Jones (1977).

To fully understand how to evacuate non-ambulatory hospital or nursing home patients, specific studies of architectural barriers and equipment along an exit route, and their consequences for unobstructed passage, are necessary. Other issues like excessively high or low coefficients of friction on walking surfaces and the heights of thresholds along the egress route also should be considered.

5.1.4 Recording the Points of Origin of Health Care Facility Fires

This issue refers to a systematic mapping of the points of origin of actual fires to establish where ignition is most likely to occur and where it is most likely to result in a fire that is serious enough to require evacuation. The topic is important because objective evacuation system design and evaluation, in large part, will be determined by an analysis of performance for the most critical conditions in which a fire is likely to occur.

Although the point of origin is almost always noted (e.g., Lefer, 1976; Lerup, 1975), it is only beginning to be the object of systematic analysis. Post-incident investigations by Haber (G. M. Haber, personal communication, 1976) have indicated that a high percentage of nursing home fires originate in rooms that are the farthest removed from the location of the nursing station. In conjunction with the British Columbia Department of Health and the National Research Council in Ottawa, J. E. Breeze and R. S. Ferguson have moved to establish a fire incident reporting system for extended care facilities which will include this kind of spatial data.

5.1.5 Field Observations of Emergency Training Procedures and Drills

This issue refers to a documentation of actual levels of staff participation and performance in in-service fire evacuation programs. This topic will supply baseline data for evaluating a staff assistant's performance during an actual fire emergency.

The work of Dynes and Quarantelli (1968), on changes in the structure of previously arranged work groups in the face of an actual emergency, provides one framework for conceptualizing this problem. Of particular interest are who does and who does not participate in the program, the amount of instruction versus supervised practice and certification, and the manner in which the characteristics of the emergency are simulated. Haber (1977) indicates that an annual staff turnover rate in excess of 50 percent tends to negate the benefit of much of the staff training for emergency evacuation in nursing homes. Similar studies have been initiated by John P. Keating and Elizabeth F. Loftus of the Department of Psychology, University of Washington. Controlled exposure to actual fire and smoke during training sessions involving the nursing, engineering, housekeeping, laboratory, clerical, and other personnel of one hospital is reported by Simon (1977).

5.1.6 Determination of Critical Design Conditions

This issue refers to the facility-specific determination of the most demanding evacuation effort that would be likely to occur. If the spatial behavior of patients and trained staff could be mapped on a working model of the unobstructed linkages between work stations, threatened patients, and safe exits, then one can predict which fire situations would be the most critical in terms of travel times per assistant, queue formation, fire growth rate, and special equipment needs. This would provide an improved basis for planning realistic staff training programs and for weighing the performance trade-offs between evacuation and detection, protection, and suppression systems for a particular health care facility. Caravaty and Haviland's (1967) work on the placement of exits includes a preliminary assessment of this problem.

5.2 PERFORMANCE MEASURES

This issue refers to statistically stable estimates of the levels of performance for required tasks during an emergency evacuation. Of specific concern is the rate at which each task can be performed under stress and the resultant cost in time or manpower lost due to energy expenditure, exposure to stress, or counterproductive allocations of effort. Since the level of performance will depend in part on each assistant's understanding of the urgency of the fire situation, attention must be given to the cues used by the patients and staff to govern their own actions during an evacuation effort. Only those research issues that bear directly on the establishment of performance criteria for trained staff assistants are listed.

5.2.1 Determination of Manpower Supply and Resupply Rates

This issue refers to measures of the elapsed time between the decision to evacuate and the arrival of the first assistant(s) at the side of the most threatened patients(s) and the intervals at which successive assistants arrive at the sides of the next most threatened patients under simulated fire emergency conditions. This includes the time that it takes the signal to evacuate to reach the available assistant(s), the termination of the assistant(s) ongoing activity, the rate at which they move toward the most threatened patient(s), the time lost to perform intervening tasks enroute (like calling the fire department or closing doors to patient rooms), the act of locating the most threatened patient(s) under low visibility conditions, and the time it takes for the assistant to get into a position where preparation can begin. Variations in the duration of these sub-tasks relate to changes in levels of information and of stress as the fire and the evacuation continues. The application of this research will require standardized models of typical architectural layouts, of typical hospital and nursing home fires, and of typical staffing practices. Lerup (1975) has described some of the factors involved in initial response times. Very little research has been done on the supply of assistants during a building evacuation.

With regard to the impact of the fire and its effects on movement speeds and direction findings, however, the research by Edmondo and Macey (1968) and Garner and Lowrey (1976) on the effects of lighting and signage on visibility through smoke is of value. In addition, considerable research on the effects of reduced visibility on walking speeds in smoke-filled corridors is being done by the Fire Research Institute of Japan (Watanabe, et al., 1973; Jin, 1976).

5.2.2 Studies of Alternative Preparation Procedures Under Stress

This issue refers to measures of the rate and efficiency with which a succession of patients can be prepared for removal under simulated fire emergency conditions. Variables to be considered include the degree of patient dependency (prosthetic and life-support requirements), the type of special equipment to be used, and the specific procedures followed by the assistant(s). Given a range of patient dependencies, research could stress the development of new equipment and techniques.

The most extensive research on patient preparation has been the fire evacuation exercise conducted by the Fire Research Station at Hackney Hospital in London (Appleton and Quiggin, 1976). That simulation used a special bedsheet which could be wrapped around a sleeping patient and used as a litter. Einhorn (1975) also has addressed the decline in task performance introduced by exposure to smoke, toxic fumes and heat.

5.2.3 Studies of the Movement Capabilities of the Elderly and Handicapped

This issue refers to measures of the maximum speed and continuity of movement on the part of patients in various mobility categories under simulated fire conditions (fire drills). In addition to speed, other important factors include: spatial requirements and maneuverability limitations imposed by the type(s) of prosthetic devices used; comparison between the speed, flexibility, and spatial requirements of moving with or without an assistant; and the direct effects of the fire on a debilitated patient's ability to maintain a steady course toward an exit. The results of such research could help determine which class of victims should or should not be assisted all the way to an exit.

Preliminary data on how fast users of various prosthetic devices can move on level surfaces in non-emergency situations has been collected by Edward Steinfeld, at the State University of New York at Buffalo, and John Templer, at the Georgia Institute of Technology. The effects of glare and other sensory factors on the routine movement capabilities of the elderly have been studied by a number of researchers (e.g., Pastalan, Mautz and Merrill, 1973). There appears to be no research on the movement of patient-assistant pairs. None of the cited research has considered movement in emergency situations, nor has the research on the effects of smoke density on walking speeds addressed the special problems of a dependent, non-ambulatory population.

5.2.4 Studies of Alternate Removal Procedures Under Stress

This issue refers to measures of the overall efficiency and effectiveness of various techniques and strategies for removing dependent patients from a threatened zone. There are two separate but related issues: (a) the actual techniques or procedures used to move patients (fireman's carry, wrap in a sheet and drag, pile several patients onto a rolling bed, etc.) and (b) the staging of the removal effort, by increments, from the point of preparation to the safe zone. However, the manner in which the patient is transported may affect how far he or she can be transported efficiently and at what cost in terms of fatigue and energy expenditure. Therefore, these two issues are considered together.

In the development and evaluation of patient transport techniques and equipment, factors to be considered include: the rate of movement and other time-based criteria, the amount of energy expended by each assistant, the manpower required per patient, and the evacuee's exposure to risks associated with removal (as opposed to risks associated with the fire itself). In assessing removal by increments (e.g., intermediate protection), changes in manpower availability over the course of the fire, the physical characteristics and condition of the exit route, and the effectiveness of the evacuation process in terms of lives saved and injuries avoided should be addressed.

The only systematic study of the removal process to date has been the timing of the simulated evacuation at the Hackney Hospital by Appleton and Quiggin (1976). Since each assistant was free to choose his or her own technique (except for the special sheets) and strategy, its results are of limited applicability. Moreover, the benefits of research on specific removal strategies, transport methods, and their interaction, will not be realized until explicit models of architectural layouts, fire development, and staffing practices for hospitals and nursing homes become widely available.

5.2.5 Studies of the Use of Information in High-Risk Decisionmaking and in Route Selection Under Stress

This issue refers to (a) measures of the impact of training and of the effects of the fire on an assistant's use of visual and other sensory cues to assess the prevailing level of risk and (b) to the assistant's selection of an appropriate course of action under simulated emergency conditions. An actual fire presents most people with a very unique context for decisionmaking. Ambiguities can be created by alterations in the cues which an assistant normally uses to orient himself or to gauge the current state of affairs, and by discrepancies between an assistant's experience in an actual fire and the expectations he gained in a training program. The consequences can be inappropriate decisions with potentially lethal implications.

Since cues are more directly amenable to control than the decisions that follow from them, it is the effectiveness of specific cues that is at issue, rather than the consequence of a specific class of decisions. The central concern, then, is how certain cues elicit certain behaviors (decisions) under various circumstances. Best's (1970) studies of direction finding in buildings under nonemergency conditions, Lerup's (1975) reconstruction of the decisions made by the staff in ten nursing home fires, and the theoretical formulations of Breaux, Canter and Sime (1976) and Canter and Matthews (1976) are among the few efforts in this direction. New research by Bickman (1977) on the effects of prior experience and familiarity on the selection of emergency egress routes and work of Tad Ogrodnik and Robert Beck for the Canadian Department of Health and Welfare on patterns of stair use for interfloor travel in high rise office buildings may shed new light on the process of route selection under stress.

5.2.6 Studies of the Effects of Overmanning on the Evacuation Process

This issue refers to tests of the inverse, perhaps U-shaped, relationship between the number of assistants involved in the evacuation effort and the total evacuation time. In the Appleton and Quiggin (1976) simulation, the total time required to evacuate 30 bed-ridden "patients" actually increased as the number of staff assistants increased. This suggests that after a certain point, having even more helpers may actually reduce overall effectiveness. Reports of several nursing home fires indicate that administrators and other supervisory staff members who have not previously participated in drills or training programs frequently take charge of an evacuation effort in an actual emergency. As a result, they often diminish the effectiveness of those more fully trained. Therefore, research on the impact of the number, status and experience of assistants on the duration and effectiveness of evacuation activities is needed if improved procedures are to be developed. Although this specific problem has received only anecdotal treatment in the evacuation literature, the theoretical basis for investigating "overmanning" (Barker and Gump, 1964) is well established.

5.2.7 Simulations of Total Evacuation System Effectiveness

This issue refers to analogs of the relationships between patient mobility status, facility layout, fire development, staff performance and total evacuation time and the cost in terms of lives lost or injuries sustained. When the parameters of the evacuation process are sufficiently understood, simulation techniques can be used to determine optimum performance criteria for either a standardized or specific health care facility. This capability would enable planners, regulators or evaluators of evacuation systems to establish the risks and benefits of a range of options regarding the provision and operation of evacuation systems for non-ambulatory hospital and nursing home residents. It also would be of value in evaluating trade-offs between evacuation, detection, supression, and protection systems in health care facilities.

There are simulations of the hydraulic model of evacuation in health care facilities. These include Henderson's (1971) use of a gas diffusion model to simulate crowd flow in nonemergency situations and Cathey's (1974) analysis of "evacuation trees." The most elaborate simulations of human behavior in building fires are by Stahl (1976) and by John Breaux at the University of Surrey. However, these do not currently address non-ambulatory building occupants.

5.2.8 Calculation of Optimal Evacuation and Training Procedures

This issue refers to the facility-specific determination of the most effective evacuation techniques and strategies, given a known patient population, physical plant, and staff capability or other local conditions. When response times, preparation times, removal rates, and decisionmaking can be mapped on the physical layout of the facility and the daily routines of patients and staff, an evacuation plan can be tailored to the needs of a specific facility. This capability would help structure drills and training programs so as to maxmimize the correspondence between the staff assistant's expectations and the actualities of the most likely fires.

5.3 INTERMEDIATE PROTECTION AND EVACUATION TRADE-OFFS

This section addresses the assessment of the risks and benefits of protecting non-ambulatory patients in place versus evacuating them to a zone of safety inside or outside the building during a fire. Since most victims of fires in health care facilities die of the indirect effects of the fire (smoke, toxic fumes or heat) rather than from the fire itself. Since most of these fires are relatively minor in terms of the area of involvement or the time to extinguishment, it has become more common to think of fire protection in hospitals and nursing homes in terms of closing the doors to the patient's rooms than in terms of total evacuation. It is assumed persons behind closed doors would be able to "ride out" the fire until it is extinguished. For example, Lefer (1976) reports four people who were unaware of a very serious fire in an adjacent room and survived because the door was closed. By contrast, there also are reports of people who waited behind a closed door until they just couldn't stand it any more and were found near death from smoke inhalation in the corridor outside their rooms (Lerup, 1975; B. Levin, personal communication, 1976). These reports indicate that a person may not voluntarily ride out a serious fire if its toxic and thermal effects are believed to be accumulating on the other side of the door that is the only means of escape. Several research issues that are related to this trade-off will be discussed.

5.3.1 Studies of Occupants' Confidence in the Fire Safety of an Intermediate Protection System During a Fire

This issue refers to measures of the effects of stress and uncertainty over relatively short periods of time on a person's willingness to remain in a protected area near the origin of a spreading fire. The issue is not how long a wall or door can resist fire and smoke, but how long a person will accept that protection as the sole means of his or her survival. Since perceptions of time are altered in stressful or high-risk situations, this perception and its effect on subsequent behavior can be quite critical.

The main concern is to understand the impact of time and of information about the fire or about attempts to contain it on a person's decision either to rely on the performance of an intermediate protection system (door or wall) despite the immediacy of a growing threat or to attempt to escape via a route that may be increasingly filled with the lethal effects of a fire. This is a precarious situation. It is possible that a person's confidence in available protection will diminish just as the need for that protection increases and as the only alternative, escape, becomes less and less viable. Unless the fire is extinguished rapidly, time would appear to work against anyone who is aware of the proximity of their refuge zone to the fire or its direct effects. Thus, to determine when and where the use of closed doors will provide adequate protection and how to inform occupants about the risks associated with riding out versus fleeing a fire, a systematic study of occupants' perception of protection in a fire emergency is needed.

5.3.2 The Impact of Closing and Closed Doors on Initial Response Time

This issue refers to measures of the extra time required to close doors and to locate victims behind closed doors while responding to the most threatened patient(s). There are two related aspects of this problem: (a) how much closing doors to patients' rooms while enroute to the most threatened patient increases the time of the intitial response, hence, the risk to that patient and (b) how much closed doors delay finding the most threatened patient(s). The first aspect is relatively straightforward. The second, however, is not because the assistant and the occupants behind closed doors both are uncertain about what is happening on the other side of the door. In order to reduce that uncertainty, each door without an unobstructed vision panel must be opened. This can expose the assistant and the occupant to the effects of the fire, and it can delay the assistant from reaching the most threatened occupant.

Additional time can be lost be opening and closing the doors to empty rooms, including doors opened and closed by earlier searchers. This suggests that there must be a standardized approach to and a shared understanding of a door's position (e.g., "open" means no one is in here or this room has already been searched). The effects of a particular approach to door position on an assistant's delay in responding to a most threatened patient should be studied.

Research on the time needed to close doors and to locate concealed occupants under simulated fire emergency conditions is urged. The British Columbia Department of Health's fire incident reporting system indicates that fires may be less readily detected and more likely to grow out of control if they begin in a room to which the door is initially closed rather than open (R. S. Ferguson, personal communication, 1976). This suggests that the flow of critical information may be obstructed when doors to patient's rooms are closed, resulting in a critical loss of time in detecting a fire or in deciding to evacuate patients. Archea's (1974) model of visual access and exposure provides a tentative framework for considering portions of this problem.

5.3.3 Simulations of Protection Versus Evacuation Options

This issue refers to analogs of the relationships between the temporal requirements of an evacuation procedure and the temporal costs of providing intermediate protection, measured against various manpower and life saving criteria. Once patient confidence and staff efficiency issues associated with using intermediate protection in hospital or nursing home fires are fully explicated, simulation techniques can be used to determine the applicability of these two options for different patient populations, building arrangements, or staffing conditions. For the most part, these simulations will probably be most useful as subroutines within the much larger simulations of the overall evacuation system (see Section 5.2.7).

In sum, once data become available for most of the research issues discussed in this chapter, it should be possible to (a) make fairly precise estimates of the total evacuation time for non-ambulatory patients in typical or specific facilities; (b) develop more appropriate staff training procedures in general or in response to special circumstances; (c) determine the risk-benefit trade-offs between evacuation systems and detection, protection, or supression systems in typical or specific cases; and (d) promulgate more realistic regulations affecting the design and management of systems for evacuating non-ambulatory patients from new or existing health care facilities.

Much of this increased capability for predicting performance in emergency evacuations would result from a more complete understanding of the effects of building factors on patient and staff behavior. Thus, it should be possible to use this research to improve the physical design of hospitals and nursing homes from a life safety viewpoint. It also should be possible to weigh the architectural implications and costs of increased fire safety against other attributes (e.g., accidents, crime) and the operating requirements of the facility (e.g. keeping the doors to patient rooms open or closed at night).

This research agenda can and should be put into a larger context because the proportion of the population represented by the elderly, handicapped or otherwise non-ambulatory patients in hospitals and nursing homes is relatively small (see Wooliscroft, 1975). The research effort, and any design or policy initiatives that might follow from it, could be of potential benefit to the much larger population of people who have limited capabilities for getting themselves out of a burning building. This larger population includes people who are asleep (the entire population, roughly one third of the time), those who are intoxicated or under the influence of debilitating drugs or medication, persons suffering from temporary illness or injury, infants and young children, and anyone else who is actually entrapped in a portion of a burning building. It also includes the elderly and handicapped in buildings other than health care facilities -- like private homes, half-way houses, department stores, recreational facilities, and places of employment (an increasing opportunity for the handicapped since the enactment of the "Rehabilitation Act of 1973" [P.L. 93-112]). Finally, it includes the indigent occupants of rooming houses and other forms of transient lodging -- a most vulnerable population in very high-risk settings. By considering this larger population of people and of building types, the effective targets of the proposed framework and recommended research program begins to encompass a significant proportion of all people and situations from which the fatalities and injuries in building fires are drawn.

6. SUMMARY AND CONCLUSIONS

The predicament of the non-ambulatory and dependent patient in a health care facility or nursing home who needs to be removed to safety during a fire emergency is addressed. The hydraulic model, predicated on ambulatory, nondependent building occupants, and with its stress on the safe end--the exits--of the emergency evacuation route, is found wanting. An alternative approach is proposed. This approach focuses on the threatened end--the end near the fire--and on the dependent and non-ambulatory patients in the vicinity of the fire.

Chapter 1 addresses the problems the non-ambulatory patient who needs assistance from others during a fire emergency if he or she is to be evacuated without serious injury or loss of life. The chapter also considers the contingent problems that the assistants or helpers, such as the facility's staff or outsiders, including firefighters, face during a fire evacuation. It is the assistants' task to prepare and remove the patients to a safe refuge, starting with the most threatened patients. Removal is conceptualized as an incremental process, and the idea of intermediate refuge is introduced. Using an intermediate refuge is hypothesized to (1) reduce the demand on the exit channel, (2) maintain a supply of assistants for other most threatened patients, while, at the same time, (3) reduce the immediate threat from the fire and its products to the dependent, non-ambulatory patients in the intermediate refuge. Incremental removal may prove to be a better use of human resources and of the facility and may result in fewer lost lives and serious injuries than removing patients, one at a time, from the threatened end to the safe end of an evacuation route.

The incremental approach is based on the assumption that the initial supply of assistants during a fire emergency will be limited but that additional assistants will become available over time. One implication of a limited initial supply of assistants is that these assistants will probably have to help more than one patient. Because of the stress and effort of providing assistance, the assistant must include a rest-and-recovery period, however brief, as part of the evacuation process. Efforts by assistants that go beyond their levels of endurance increase the risks to the health and safety of assistants and, by implication, to those who the assistants are helping or could have helped (had the helpers been able to continue with assisting patients).

Based on the description in Chapter 1, Chapter 2 reconceptualizes the evacuation process into five sequential phases: the manpower supply phase, the patient preparation phase, the patient removal phase, the rest and recovery phase, and the manpower resupply phase. For each phase of the evacuation process, its most critical and the most effective portions are described and the role of building, patient and staff including staff decision factors are discussed. The purpose of the reconceptualization is to provide a framework for assigning priorities to building, patient and staff factors that can control the success or failure of the evacuation process.

Chapter 3 addresses the potential relationships among the phases presented in Chapter 2. The five phases, and the parameters and measures described in Chapter 3, illustrate the variables which a model of the evacuation process must include. The system parameters and measures are (1) the process of fire development, (2) the mobility status of patients, (3) the locations of persons (patients and staff) and the physical layout and condition of settings in a facility, which is called "spatial distribution," (4) task proficiency of assistants, and (5) system performance measures. Examples of systems performance measures are "removal rate," or the rate at which dependent patients are removed from a fire zone, and "margin of sufficiency," or the removal rate minus the rate of fire development.

Chapter 4 discusses the design and assessment of evacuation systems. Specifically, it is argued that the analysis of the evacuation process is, ultimately, a matter of measuring initial conditions, such as patient mobility and the physical layout of a facility, and of measuring system performance, such as how assistants are expected to carry out evacuation tasks during an actual fire. Approximations of initial conditions and performance factors are introduced--in the form of 14 assumptions--as guidelines for the design and assessment of evacuation systems.

The review of critical initial conditions and ideal performance conditions in Chapter 4 suggests that there has been little research on the movement of non-ambulatory hospital and nursing home patients under emergency conditions. Chapter 5 proposes a research agenda to develop needed information. The chapter reviews the available literature and recommends a number of studies on the evacuation process. Two areas are emphasized for a concerted research effort. They are: actual performance levels under real emergency conditions in hospitals and nursing homes, and spatial and mobility aspects of routine health care activities. A third, narrower, area also is recommended: intermediate protection and evacuation trade-offs. The results of this research could provide the level of understanding required to design and assess evacuation systems for the non-ambulatory and dependent individual and to formulate policies for fire emergencies involving threatened populations. The chapter also discusses the potential applicability of the results of the recommended research effort to additional population and building types.

In conclusion, the major life safety issue in building fires is, by definition, the problem of all people who cannot begin to move away from the effects of a fire fast enough to avoid its debilitating or fatal consequences. The measure is not the number of lives saved, it is the number lost. If this preliminary analysis of the evacuation of non-ambulatory hospital or nursing home patients has shown anything, it is that the most critical portion of the evacuation process for the non-ambulatory person lies at the "threatened end" of the evacuation circuit.

Therefore, anyone who seriously intends to reduce the deaths and injuries resulting from building fires will have to give much more consideration to the fire victim at the threatened end. This is the target toward which further research ought to be directed, to which new regulations ought to be addressed, and to which the design and evaluation of evacuation, protection, and training programs ought to be focused.

REFERENCES

Appleton, I., and Quiggin, P. "Hackney Hospital Fire Precautions Project FRS Contribution: An Evacuation Model." Operation Research and Systems Studies Section, Fire Research Station, Building Research Establishment, Borehamwood, U.K., 1976.

Archea, J. "Identifying Direct Links Between Behavior and Its Environment: Toward A Predictive Model." In T. O. Byerts (Ed.), Environmental Research and Aging. Washington, D.C.: Gerontological Society, 1974.

Bader, J., Maxwell, R., and Watson, W. "Doomed Status and the Ecology of Institutions," Paper Presented at the 25th Annual Meeting of Gerontological Society, San Juan, P.R., December 1972.

Baer, E. "A Simulation Model of Multidirectional Pedestrian Movement Within Physically Bounded Environments." (Report No. 47). Institute of Physical Planning, Carnegie-Mellon University, Pittsburgh, 1974.

Barker, R. G., and Gump, P. V. Big School, Small School. Stanford, CA: Stanford University Press, 1964.

Best, G. "Direction Findings in Large Buildings." In D. Canter (Ed.), Architectural Psychology, London, U.K.: R.I.B.A. Publications, Ltd., 1970.

Bickman, L. Presentation at the Seminar on Behavior in Fires, University of Surrey, Surrey, U.K., March 1977.

Breaux, J., Canter, D., and Sime, J. "Psychological Aspects of Behavior of People in Fire Situations." Fire Research Unit, University of Surrey, Surrey, U.K., 1976.

Bryan, J. L. "Human Behavior in Fire Situations." (Paper Prepared for the Second Joint Panel Meeting on Fire Safety and Research, Tokyo, Japan, October 19-23, 1976). College of Engineering, University of Maryland, College Park, October 1976.

Canter, D., and Matthews, R. "Behavior in Fires: The Possibilities for Research." (CP 11/76). Borehamwood, U.K.: Fire Research Station, Building Research Establishment, 1976.

Caravaty, R. D., and Haviland, D. S. "Life Safety From Fire: A Guide for Housing the Elderly." Troy, N.Y.: Center for Architectural Research, Rensselaer Polytechnic Institute, 1967.

Cathey, B. H. "A Technique for Analyzing Building Evacuation Plans and Facilities Designs." American Society of Safety Engineers Journal, 1974 (August), 26-28.

Dynes, R. R., and Quarantelli, E. L. "Group Behavior Under Stress." Sociology and Social Research, 1968, 52(4), 416-429.

Edmondo, P. M., and Macey, H. T. "An Investigation of Lighting Directional Markers for Emergency Egress from Ships Compartments. Phase I, Study: Lighting Investigation." (Report No. 3561). ANNADIV NAVSHIPRANDCEN, February 1972.

Einhorn, I. N. "Physiological and Toxicological Aspects of Smoke Produced During the Combustion of Polymeric Materials." In Proceedings NSF/RANN Conference on Fire Research, Harvard University, Cambridge, MA., June 1975.

Ferguson, R. S. "Fire at Extendicare Ottawa, Sunday, 3 August 1975," Division of Building Research, National Research Council of Canada, Ottawa, 8 August 1975. (Memorandum)

Fruin, J. J. Pedestrian Planning and Design. (Chapter 3: "Traffic and Space Characteristics of Pedestrians.") New York: Metropolitan Association of Urban Designers and Environmental Planners, Inc., 1971.

Garner, J. D., and Lowrey, D. L. "Exit Sign Comparisons in Clear Air and Smoke." Unpublished Manuscript. Office of Aviation Medicine, Federal Aviation Administration, Washington, D.C., December 1976.

Gump, P., and James, E. V. "Patient Behavior in Wards of Traditional and of Modern Design." The Environmental Research Foundation, Topeka, KS, 1970.

Haber, G. M. Presentation at the Seminar on Behavior in Fires, University of Surrey, Surrey, England, March 1977.

Henderson, L. F. "The Statistics of Crowd Fluids." Nature, 1971, 229, 381-383.

Ittelson, W., Rivlin, L. G. and Proshansky, H. M. "The Use of Behavioral Maps in Environmental Psychology." In H. M. Proshansky, W. H. Ittelson, and L. G. Rivlin (Eds.), Environment Psychology: Man and His Physical Setting. New York: Holt, Rinehart and Winston, 1970.

Jin, T. "Visibility Through Fire Smoke (Part 5: Allowable Smoke Density for Escape From Fire)." Report of the Fire Research Institute of Japan, 42, No. 42, September 1976, pp. 12-18.

Johnson, B., and Jones, B. "Draft Report on the Problems of Patient Removal in Buildings." Division of Building Research, National Research Council of Canada, Ottawa, 1977.

LeCompte, W., and Willems, E. "Ecological Analysis of a Hospital: Location Dependencies in the Behavior of Staff and Patients." In J. Archea and C. Eastman (Eds.), ERDA Two. Stroudsburg, PA: Dowden, Hutchinson and Ross, 1970.

Lefer, H. "Where There's Fire There's Smoke." Progressive Architecture, 1976 (September), 58-63.

Lerup, L. "Mapping Behavior: The Case of Fire." (Working Paper No. 5.) University of California, Berkeley, 1975. Also available as: Lerup, L., Greenwood, D., and Burke, J. S. Mapping of Recurrent Behavior Patterns in Institutional Building Under Fire: Two Case Studies of Nursing Facilities. (NBS-GCR-76-73.) Washington, D.C., National Bureau of Standards, July 1976. Available from NTIS as PB257424.

Lippert, S. "Travel as a Function of Nursing Unit Layout." In H. H. Field, J. A. Hanson, and C. J. Karalis, Hospital Design Evaluation: An Interdisciplinary Approach (Appendix IV). (Report No. MSRD 73-14, PSH-HS-00133.) Boston: New England Medical Center, December 1971. (a)

Lippert, S. "Travel as a Function of Nursing Unit Layout, with Utility Stops." In H. H. Field, et al., Hospital Design Evaluation: An Interdisciplinary Approach (Appendix V). Boston: New England Medical Center, December 1971. (b)

Lippert, S. "Travel in Single Corridor Nursing Units Ranging From 1-84 Beds." In H. H. Field, et al., Hospital Design Evaluation: An Interdisciplinary Approach (Appendix VI). Boston: New England Medical Center, December 1971. (c)

Murray, M. "Comparison of Free and Fast Speed Walking Patterns of Normal Men." American Journal of Physical Medicine, 1966, 45(1), 8-24.

Pastalan, L., Mautz, R. K., II, and Merrill, J. "The Simulation of Age Related Sensory Losses: A New Approach to the Study of Environmental Barriers." In F. E. Preiser (Ed.), Environmental Design Research (Vol. I: Selected Papers). Stroudsburg, PA: Dowden, Hutchinson and Ross, 1973.

Pauls, J. L. "Fire Safety and Related Man-Environment Studies." Man-Environment Systems, 1975, 5(6), 386-394.

Simon, F. J. "Learning to Put Out Hospital Fires." Fire Journal, 1977 (January), pp. 75, 77.

Srivastava, R., and Good, L. R. "Patterns of Group Interactions in Three Architecturally Different Psychiatric Treatment Environments." The Environmental Research Foundation, Topeka, KS, March 1968.

Stahl, F. I. "Some Prospects for Simulating Human Behavior in High-Rise Building Fires: A Pilot Demonstration." In P. Suedfeld, and J. Russell (Eds.), The Behavioral Basis of Design. Stroudsburg, PA: Dowden, Hutchinson and Ross, 1976.

Stahl, F. I., and Archea, J. An Assessment of the Technical Literature on Emergency Egress From Buildings. (NBSIR 77-1313). Washington, D.C.: National Bureau of Standards, October 1977.

Steinfeld, E. Specifications for Making Buildings and Facilities Accessible to and Usable by Physically Handicapped People. Proposed ANSI A117.1 (1977). Syracuse, N.Y.: Syracuse University, 1977.

Tashida, S. "Walking in the Midst of Smoke." Resume of Symposium Reports, Symposium on the Physical, Psychological and Behavioral Aspects of Fires, Japan Fire Science Assn., November 1975.

Trites, D. K., Galbraith, F. D., Sturdavant, M., & Leckwart, J. F. "Influence of Nursing-Unit Design on the Activities and Subjective Feelings of Nursing Personnel." Environment and Behavior, 1970, 2(3), 303-334.

Watanabe, Y., Nayuki, K., and Torizaki, K. "Actions of Firemen in Smoke." (Report No. 37). Fire Research Institute of Japan, Tokyo, 1973.

Wehrli, R., and Kapsch, R. Hospital Bedrooms and Nursing Units. A Systems Approach for Building Technology. (PB 218-975). Springfield, VA: National Technical Information Service, 1972.

Wood, P. G. "The Behavior of People in Fires." Department of the Environment and Fire Office's Committee, Joint Fire Research Organization, U.K., November 1972.

Wooliscroft, M. J. "The Hospital Fire Problem: Towards a Rational Approach." Doc. Eng. 265, November 1975.

Appendix 1. Schematic Diagrams of the Evacuation Process

Chapter 1 contains seven schematic diagrams of the evacuation process. Each diagram maps factors and their interrelations that are discussed in Chapter 1. Each of the six sections in chapter 1 has its own schematic diagram (Figures 1-6). The final diagram, Figure 7, entitled "Summary of Major Factors," summarizes the interrelations of the factors that appear in Figures 1-6.

The figures refer to factors by symbols. The symbols are based on first letters of key words that describe the factors that are represented. A key to the symbols appears on the next page. In the key, symbols are listed in alphabetical order; the factors to which they apply are described; and the figures in which each symbol appears are listed. The symbols in a figure first appear in brackets in the section of Chapter 1 that references the figure.

The figures indicate the position of the factors on a "maximum threat-maximum safety" dimension. The maximum threat-maximum safety dimension "scale" appears at the bottom of each figure.

Each figure consists of a series of wide-bodied "arrows"; each arrow is a unit of behavior that takes a period of time to complete and that involves one or more persons. The nature of the behavior is indicated by the symbol in the arrow. Each arrow (unit of behavior over time) has an initial position on the maximum threat-maximum safety dimension (the "tail" of the arrow), a path of movement on the dimension (the "body" or "shaft" of the arrow) and a final position and direction (the "head" indicates the final position and the direction the "head" faces indicates the direction).

To illustrate how to read "threat-safety" for a factor, turn to Figure 7 (page 16). The self-evacuating patients, SE, start at the threat end of the dimension and move toward and reach the safe end. By contrast, the resupplied manpower, RM, starts at an intermediate position on the dimension and moves toward the threat end. As for the self-starting patients, SS, they do not change their position on the dimension. This is indicated by an arrow that remains in a vertical plane. These patients start at the threat end and, during their start-up activities, remain at the threat end.

Thus, each figure presents factors, their interrelations, and specifies whether the behaviors that are represented move the person(s) toward threat or toward safety or leave them in an unchanged position on the maximum threat-maximum safety dimension.

Key to Figures 1-7

Symbol	Corresponding Factor	Appears in Figures:
A	Ambulatory status of patients after preparation.	3,7
AP	Evacuation assistance provided by trained assistants.	3,5
AR	Evacuation assistance required or received by non-ambulatory patients.	3,7
AR_1	The partial assistance received by non-ambulatory evacuees.	6,7
AR_2	The continuation of assistance received by non-ambulatory evacuees.	6,7
CA	The continuation of assistance given to non-ambulatory evacuees.	6,7
d	A "distant point" at which the assistant is initially located.	4,7
i	An "intermediate point" to which evacuees are first moved.	6,7
IS	The initial supply of manpower.	4,5,6,7
LS	The later supply of manpower.	6,7
MS	The total manpower supply for the patient population.	5,7
N-A	The non-ambulatory status of patients after preparation.	3,7
PA	The partial assistance given to non-ambulatory evacuees.	6,7
PP	The preparation provided by trained assistants.	2,4,6,7
PR	The preparation required or received by dependent patients.	2,7
R&R	The rest and recovery required by assistants to offset the effects of fire and fatigue.	5,6,7
RM	The resupply of manpower.	2,7
s	The "safe end" of the evacuation route.	2,7
SE	The self-evacuating action of independent, ambulatory patients.	1,3,7
SS	The self-starting action of independent, ambulatory patients.	1,2,7
t	The "threatened end" of the evacuation route.	2,7

NBS-114A (REV. 9-78)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBSIR 79-1906	2. Gov't. Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE The Evacuation of Non-Ambulatory Patients from Hospital and Nursing Home Fires: A Framework for a Model	5. Publication Date November 1979 6. Performing Organization Code
7. AUTHOR(S) John Archea, Author and Stephen Margulis, Editor	8. Performing Organ. Report No.
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, DC 20234	10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (*Street, City, State, ZIP*) U.S. Department of Health, Education, and Welfare Public Health Service Washington, D.C.	13. Type of Report & Period Covered 14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT (*A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.*)

This report is directed toward the problem of evacuating dependent, non-ambulatory persons from fires in nursing homes and other health care facilities. It deals only with those behavioral and building factors that bear on the activities that follow directly from a decision to evacuate patients from a fire zone in a nursing home or similar facility. The examination is based on the rejection of the model which is the basis for current life safety regulations because it assumes independent occupant mobility. This assumption does not apply to dependent, non-ambulatory persons. The major objective of the report is to identify those factors that must be considered in order to determine the ideal performance of a hospital or nursing home evacuation system for non-ambulatory patients when all components or persons in that system act as they are designed or trained to act. These factors are presented as part of an analysis of evacuation as a five phase process: manpower supply phase, patient preparation phase, patient removal phase, rest and recovery phase, and manpower resupply phase. Research findings are reviewed and a research agenda is proposed.

17. KEY WORDS (*six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons*)

Building codes; building evaluation; elderly; fire safety; handicapped occupants; health care facilities; nursing homes; user needs.

18. AVAILABILITY	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PRINTED PAGES
☒ Unlimited ☐ For Official Distribution. Do Not Release to NTIS ☐ Order From Sup. of Doc., U.S. Government Printing Office, Washington, DC 20402, SD Stock No. SN003-003- ☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161	UNCLASSIFIED	64
	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price $5.25

USCOMM-DC