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Human Factors Considerations in the Potential for Using Elevators in Building Emergency Evacuation Plans

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Notice

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HUMAN FACTORS CONSIDERATIONS in the POTENTIAL FOR USING ELEVATORS IN BUILDING EMERGENCY EVACUATION PLANS

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ABSTRACT

If elevators could be safely used in fire emergencies, the safety of building occupants with mobility limitations could be greatly enhanced and the time for all occupants to evacuate might be reduced. This report covers a study of human factors considerations related to the possible use of elevators for evacuations in fire emergencies. It covers the selection of the fundamental approach to organizing elevator evacuations for specific buildings; the coordination and direction of the evacuation; the decision-making, information and communication needs to permit a coordinated evacuation; and the documentation, manning and training requirements to permit a proper implementation of the fire emergency plan.

INTRODUCTION

WHY CONSIDER THE USE OF ELEVATORS TO EVACUATE BUILDING OCCUPANTS?

For twenty years the American public has been trained to avoid the use of elevators during fire emergencies. Warning signs at elevators tell people not to use the elevators during fire evacuations. The dangers of using elevators during fire is well known and accepted by both laymen and experts. Nevertheless, it is likely that the technology now can be developed to provide a safe fire evacuation using elevators in tall buildings.

Assuming that there are no insurmountable technological hurdles, are there good reasons for using elevators during a fire emergency? Some possible reasons are listed as follows:

- Elevators could be used to evacuate persons with disabilities who can not descend stairs without assistance or significant risk of additional injury.
- Elevators, used in conjunction with stairs, would reduce the amount of time needed to completely evacuate large buildings.
- Even for persons without disabilities, descending many flights of stairs is an onerous task in very tall buildings.
- Fire fighters could use fire safe elevators to move personnel and equipment over long vertical distances with greatly enhanced safety and reliability.

SCOPE OF THE PROJECT

The National Institute of Standards and Technology (NIST) is conducting a research program to determine the feasibility of fire safe elevators. Specifically, NIST is developing performance based techniques for occupant use of elevators during building evacuations, developing analytical methods for these techniques, and evaluating these techniques. This program involves two complementary efforts:

- An analysis of the feasibility and design considerations of emergency evacuation by elevators.
- An analysis of human factors considerations of emergency evacuation by elevators.

This report is concerned with the second effort. It is an examination of the obstacles and opportunities to having building occupants use elevators. While the issue of whether occupants will accept elevator evacuations is the most obvious obstacle, we have attempted to address all aspects of human behavior that affect the success of elevator evacuations.

This paper is based on the assumption that it is dangerous to prepare half-heartedly for an evacuation on the assumption a fire emergency evacuation would be unlikely.

It is likely that buildings with fire safe elevators would also be fully sprinklered. The installation of sprinklers decreases the probability that there will be a fire emergency that requires evacuation of the building. This paper is written on the assumption that there still will be a need to be prepared for fire evacuations. An analysis or discussion of this assumption is beyond the scope of this report.

Fire safe elevators can be used by the general population of the building or by only those occupants who have mobility related disabilities. These are options available to building management. This paper is written on the assumption that the general population will use the elevators in a fire emergency. If use is restricted to occupants with disabilities, most of the analysis will still apply with modifications that should be obvious to the reader.

THE NEED TO USE A COMPREHENSIVE SYSTEMS APPROACH

Building features, fire protection hardware, and human behavior interact in determining whether a building successfully protects its occupants. It has been our experience that the design and installation of fire protection systems can not be successfully divorced from the people they are designed to protect. Efforts to "engineer-out" human behavior are generally unsuccessful. Even the most reliable of fire protection systems, sprinkler systems for example, rely on occupants' actions that do not compromise system integrity. Building staff and occupants must be motivated and know enough to not obstruct sprinkler heads and to periodically check and maintain the systems. Other types of systems, such as evacuation systems, are much more dependent on human behavior.

Just as the performance of fire protection systems can not be divorced from people, the safety and behavioral responses of building occupants depend inextricably on the design and functioning of building features and hardware. The layout and protection features of buildings will determine safe locations and egress routes within buildings. Alarm systems will determine whether fire are detected and occupants notified in a timely fashion.

Lessons learned from our study of staging areas. Just prior to starting this study, the authors completed an evaluation of the human factors involved in making staging areas useable and safe (Levin and Groner 1992). The General Services Administration (GSA) had installed staging areas in six Federal buildings. These staging areas are intended for use by persons with disabilities who are unable to use stairs. The staging areas provide them with temporary refuge until such time as they can be rescued. The staging areas were of two general types. Large staging areas involved the compartmentalization of floors using fire-rated barriers, similar in approach to the use of horizontal exits in health care facilities. Small staging areas were rooms equipped with ventilation/pressurization systems, fire rated barriers, and communications systems.

Many of the findings from our evaluation generalize to elevator evacuations. We discuss these findings at relevant points throughout this report. However, none of our findings is more pertinent and important than the generalization that a systems approach is vital to the design and implementation of both staging areas and elevator evacuations. We can not doubt the good intentions and technical competence of the people who designed the staging areas. Nonetheless, we believe that a comprehensive systems approach that incorporates human behavior would have allowed them to circumvent many, if not all, of the problems we discovered that were associated with people using these areas.

THE LIFE SAFETY SYSTEMS APPROACH

We believe that the best approach to analyzing the use of elevators to evacuate building occupants is to design systems specific to individual buildings. However, prior to studying specific buildings, it is necessary to consider problems that are generic to all buildings that might have elevators that could be used in evacuations during fire emergencies. This information can be used in designing the anticipated elevator system for a specific building. It serves as a guide to the types of things that must be considered to construct and implement successful elevator evacuations.

Our approach is to take an all-inclusive systems view of building emergencies for the specific purpose of life safety. The approach does not explicitly consider the preservation of property, although such goals are a natural consequence of pursuing life safety goals.

The life safety system approach differs from systems approaches traditionally used in fire protection in the one or all of the following ways:

- Teleological -- the performance goals of the system are explicitly stated in the form of life safety strategies.
- Temporal -- events occur in realtime, and can be modelled accordingly.
- Comprehensive -- building occupants, as well as the building features and hardware, are all included.

Each of these three attributes of the approach are discussed in the following sections.

THE APPROACH IS TELEOLOGICAL - LIFE SAFETY STRATEGIES

A building emergency system based on the life safety systems approach is based on a set of strategies, all with the objective of keeping building occupants away from smoke and fire conditions. The set of strategies is the starting point. Systems components are discussed in relation to their contributions to completing a strategy.

We sometimes refer to a "set of strategies," because there may be a separate strategy for each floor or group of floors and there may be backup strategies.

A "life safety strategy" has been defined as "a general plan for protecting building occupants from being exposed to the flames and smoke of a fire." (Groner 1985, 1989). A strategy can be expressed as a short statement that describes the fundamental actions that building occupants follow in a fire emergency. A few examples are: "Everyone in the building leaves using the nearest exit," and "The alarm alerts building occupants that they may need to evacuate. Floor wardens are notified when their respective floors should evacuate, and which stairway should be used."

Later in this section, we will discuss the details of choosing various strategies for evacuating buildings using elevators. However, a few examples of sets of strategies for occupants of upper floors will clarify their application to the problem under study. (Note that in the examples, a single building uses more than a single strategy depending on the area in the building and the people involved. Also, these are not recommendations, but are offered only as examples.)

Example 1: Persons unable to descend stairs report to the nearest elevator lobby to be evacuated using elevators. All other building occupants use the nearest stairs to descend and leave the building.

Example 2 All persons on the fire floor and the adjacent floors above and below, who are able to use stairs, either: 1. evacuate the building if the fire is on one of the first four floors or 2. descend three flights of stairs and wait for the elevator. All other persons go to the elevator lobby and wait for an elevator.

THE APPROACH IS TEMPORAL

The approach recognizes the dynamic and changeable nature of a fire emergency. As time passes, the nature of the fire threat changes. It might be quickly controlled by an automatic sprinkler, or it might grow and spread throughout the floor or even spread to another floor. At the same time, the occupants are taking action. They may be moving to other areas in the building. Safety is achieved if, for each area in the path of the fire and smoke, all occupants leave before fire, hot air, or toxic smoke enters and makes conditions untenable.

A measure, commonly used in the life safety systems approach, is the difference in time between: (1) when the last occupant leaves an area, and (2) when conditions in the area become dangerous or untenable. This difference in time has been labelled a "safety margin" by Groner (1982).

Life safety strategies can be evaluated and compared under a wide variety of fire scenarios by using the size of the safety margin as a criterion. Fire scenarios can be predicted using expert judgment, computer models, or a combination that predicts the spread of fire and products of combustion to various areas in a building. Life safety strategies can be used to direct people away from and to various areas in the buildings. By using measures of both fire spread and people movement, we can predict which strategies will provide greater safety margins to building occupants.

THE APPROACH IS COMPREHENSIVE

The life safety systems approach is comprehensive - fire protection features of the building, its physical layout, and the people occupying the building are all components of the system. Any and all of these components may affect the progress of the fire and the survival of the occupants.

Components may be "active" or "passive." An active component performs an "action" in response to a fire-relevant change in the system. "Fire protection systems" are components of the system which may be active or passive. A fire-rated wall is passive because it does not perform an action. But smoke dampers and sprinkler systems are active because they do react to fire-related conditions or events.

People are always active components. As soon as they become aware of any fire-relevant condition, people become active components. Even when they decide to remain in the same area, they are active, because this involves the action of processing of information and a resulting decision to remain in the area. In our discussions, we generally refer to the actions that people take, even though people per *se* are components of life safety systems.

A TYPOLOGY OF SYSTEMS COMPONENTS AND COMPONENT ACTIONS

Systems components and component actions can be categorized using two dichotomous parameters: (1) whether or not the components are "tractable;" and, (2) whether or not occupant behavior is involved in determining the contribution of the component during the fire incident. This typology yields a 2x2 matrix or table as shown in figure 1. One of the quadrants contains tractable components/actions with significant occupant involvement during the fire incident. This quadrant is the main focus of this study.

Tractability. Certain systems components are tractable in the sense that designers of fire protection systems and emergency planners have some control over their characteristics and inclusion. Others components are intractable -- they are determined by people or factors beyond the control of the those responsible for the evacuation system. Reasons why such components are intractable include: (1) economics overwhelm design considerations; (2) the building already exists and is occupied; and, (3) persons responsible for designing the evacuation system have not been given the necessary authority or resources.

Note that whether or not a component is tractable will often vary from building to building. For example, the tractability of many components will depend on whether the designer is working on new or existing construction. In new construction, the tendency is for fewer components to be intractable. However, major retrofits often provide opportunities to alter many components in existing buildings.

Many intractable components must be carefully considered because they strongly impact the performance of an elevator evacuation system. Thus, the designer needs to compensate for components that interfere with systems performance. For example, the installation of sprinklers is a way of compensating for barriers with unfavorable fire resistance characteristics. Or, alternatively, a strategy can be used that limits the waiting time in an area to an acceptably short amount of time.

Effort should not be directed at analyzing how to change intractable components. Instead their characteristics should be considered as given. The life safety system should compensate for any associated problems and capitalize upon potential strengths of these intractable systems components.

Figure 1 - EXAMPLE CATEGORIZATION OF LIFE SAFETY SYSTEM COMPONENTS

	TRACTABLE	INTRACTABLE*
DIRECTLY RELATED TO OCCUPANT ACTIONS DURING THE FIRE INCIDENT	Selection of life safety strategies Procedures for coordinating the use of elevators Algorithms that automatically control elevator evacuations Protocols for deciding when elevators and areas are safe to use Selection of control room locations Staffing for control center Built features of the control room (e.g., displays, lighting, background noise, space, vulnerability to fire) Task assignments for persons filling roles on the emergency team Selection of persons to fill emergency roles, including keeping assignments current Training program for coordinators Training program for emergency team members (e.g., drills, training sessions) Training program for occupants at large Relations between building management and the fire department Presumptions of the fire department about the system Selection of communications equipment Alarm notification equipment Built features of elevator lobbies (e.g., seating, lighting, background noise, doors) Signage Selection of alternative areas of safety if smoke enters elevator lobby Maintenance of hardware features	Availability of suitable locations for control rooms in existing buildings Availability of suitable location for elevator lobbies in existing buildings Availability of alternative areas of safety if smoke enters elevator lobbies Number, location, speed and capacity of elevators in existing buildings Location of stairs relative to elevator lobbies Number of building employees Abilities of building employees Relations between building management and tenants Occupancy loads Numbers and types of tenants Numbers of persons with disabilities who cannot easily descend stairs Interest and attitudes of the fire department about elevator evacuations
NOT DIRECTLY RELATED TO OCCUPANT ACTIONS	Construction of smoke control systems Protection of features of elevator systems Size of elevator lobbies	Building height Suitability of existing buildings for smoke control systems Sprinklers Building construction Fire detection equipment

* From standpoint of building management

The involvement of occupant behavior. All systems components, whether tractable or intractable, are part of the life safety system and as such are interrelated. All hardware components have potential impact on the actions of occupants. For example, if sprinklers extinguish the fire, occupants can remain in elevator lobbies and will remain safe indefinitely, and will not need to pursue backup strategies. However, the converse is not always true. The behavior of occupants during a fire emergency **will not** affect some hardware components. For example, the procedures followed and decisions made by building occupants **will** not affect the operation of a sprinkler system. For the purpose of our analysis, whether or not occupant behavior mediates the impact of a component on systems performance is another useful dichotomy for categorizing system components. Since we are concerned with human factors, our analysis emphasizes components that are mediated by occupant behavior.

The accompanying matrix (figure **1)** provides examples of components that fall within each quadrant of the typology of systems components. Tractability is from the point of view of the building manager. (It is interesting to note how few components are not directly related to occupant behavior.)

OUR ANALYSIS COVERS TRACTABLE COMPONENTS RELATED TO OCCUPANT BEHAVIOR

Scope of this study. The primary concern of this study can be delimited by the simple typology of systems components and actions just presented, namely, systems components/actions that are tractable and that are directly related to occupant behavior. (Nonetheless, components in other quadrants of the typology must inevitably be examined, because we are dealing with a system.)

Tractable components/actions involving human behavior can be divided conveniently into four categories. A major section of this report is devoted to each of the following:

- Selection of strategies — different fundamental approaches to organizing elevator evacuations.
- Coordinating and directing the evacuation — the decision-making, information, and communications needs of persons who are expected to direct the evacuation.
- Carrying out the evacuation — the decision-making, information, and communications needs of building occupants who are expected to evacuate the building.
- Implementing the fire emergency plan — the documentation, manning, and training issues involved in translating the life safety strategies to a ready and workable emergency system.

Analytical approach used in this study. Because we are considering elevator evacuation in a generic building, our analysis is necessarily general. Nonetheless, the life safety system approach can be used by examining the tractable components related to occupant behavior using a functional analysis. A functional analysis simply involves a qualitative study of the "function" that components play in accomplishing a set of life safety strategies. For example, in another section of this study, we analyze in some detail the use of a computer to coordinate and direct the routing of elevators. In that analysis, we conclude that a computer becomes more valuable as a larger set of strategies is used in a single building.

Using the life safety systems approach to analyze elevator evacuations in specific buildings. The life safety strategies can serve as the basis for both writing an emergency plan, and selecting and designing the many components that will enable the use of elevators to evacuate people. The designer tries to determine how good a "fit" there is between the strategies and the building, taking into consideration its size and layout, fire protection features and occupants (i.e., the systems' components). To the degree that the fit is unsatisfactory, changes can be made to systems components (the emergency plan, the building, and its features). Also, alternative sets of strategies can be compared to discover whether one is a better fit than the others.

LIMITING THE SCOPE OF THE SYSTEM STUDIED

We have arbitrarily delimited the study to a more manageable size by making some assumptions about the components and operation of the fire safety systems being considered. Our intent is for the results of this study to apply to most large multi-storied office buildings that have installed elevators that can safely be used for evacuation during fire emergencies. We believe that this limiting of the scope of the systems being studied will not adversely affect our achieving this goal. The importance of the limitations will vary according to the set of life safety strategies used for a particular building. For example, we assume a certain capacity for stairs, but a total evacuation using elevators might require a lesser capacity. Several assumptions are made about the presence and performance of certain components that are not generally installed in buildings, but are very likely to be required for any system that can be used to safely evacuate persons using elevators. For this reason, our report will pertain primarily to new buildings or buildings with extensive retrofits. Some of the assumptions we have made to limit the scope are:

- Exit routes, including stair capacity, meet requirements of modem building and fire codes, such as the 1991 Edition of the Life Safety Code, but do not exceed those capacity requirements. (We do not wish to consider situations where the lack of stair capacity prevents the use of stairs as an alternative route of egress nor situations where the stair capacity is so large that the use of elevators would not decrease congestion in the stairways of a high rise building.)

- The building fire protection system (i.e., compartmentation, sprinklers, etc.) will retard the growth and spread of fire sufficiently to permit an orderly evacuation for all anticipated accidental fires.

- Elevator lobbies will always be accessible to persons unable to descend stairs, i.e., no steps between offices and elevator lobbies.

- If a group of elevators is not involved in the fire nor is in the primary path of smoke flow, its elevator lobby will provide an area of safety for a long enough period of time to permit its occupants to be evacuated by elevators.

- The elevator system has been designed to resist water and water from sprinklers and fire fighting will not stop elevators.

- Elevators have been designed with a reliable electric system and we will not address the problem of failure.

- The building is designed and built with features intended to retard the vertical spread of the fire for a length of time sufficient to permit long waiting times on most floors located above the fire.

SELECTION OF STRATEGIES

SELECTING AND USING CANDIDATE SETS OF STRATEGIES

There isn't any single strategy that will work for all the occupants in a large office building. Depending on their locations in the building, their proximity to the fire, and their abilities to descend stairs, different occupants may need to use different strategies. The occupant load in the building, its height, and the need for the fire department to use stairs can also affect the selection of strategies. All these factors interact, and need to be considered when selecting candidate sets of strategies.

A system for evacuating occupants using elevators should be tailored to specific buildings. This is advisable because buildings vary not only in their physical characteristics, but in such ways as relations between tenants and building management, the numbers and types of occupants, and so forth. The Life Safety Systems approach can be used to develop a set of elevator evacuation procedures for specific buildings.

The starting point is to select a candidate set of strategies. The researcher/designer tries to determine how good a "fit" there is between the strategy set and the building, taking into consideration its size and layout, fire protection features and occupants (i.e., the systems' components). Alternative strategies can be substituted in the set to discover whether one seems to offer a better fit than the others. For example, the designer may decide that elevator capacity is insufficient to evacuate all occupants from upper stones, so its use will be limited to persons with disabilities on all floors, and other occupants on selected floors. Several iterations may be needed where changes are made in both the strategies and the systems.

The set of strategies serves as the fundamental criterion for selecting and designing the many components that will enable the use of elevators to evacuate people. This approach may be used in the design of both new buildings and retrofits. To the degree that the fit between the building and the set of strategies is unsatisfactory, changes can be made to systems components (the emergency plan, the building, and its features). For example, the designer may decide that a high quality communications system is needed so that occupants waiting in elevator lobbies can be kept appraised of their anticipated wait for an elevator.

In this report we are considering problems that apply to all office buildings in which elevators are used in evacuations during fire emergencies. This information can be used in designing the anticipated elevator system for a specific building and in selecting the set of fire safety strategies for that building. In this section we will discuss the general nature of the **evacuation plans that might be selected** and **some specific examples.**

A number of factors interact and should be considered when selecting a set of strategies. We have identified the following three areas of concern, each of which is discussed in a section of this chapter.

- Stairs and elevators as a limited resources
- The abilities of occupants to use stairs
- Proximity to the fire

STAIRS AND ELEVATORS AS LIMITED RESOURCES

Occupants on upper floors must use either stairways, elevators, or a combination to descend to a floor with an exit to the outside. Firefighters must use either stairways, elevators, or a combination of both to ascend to the staging and fire floors. If we think of the stairways and elevators as scarce resources, we must prioritize or ration their use. While this terminology may not be common in fire safety, the concept is well established. In a tall building, the capacity of the stairways is usually insufficient for all occupants to attempt evacuation at the same time without a level of congestion in the stairways that impedes evacuation and causes intolerable delays in evacuating the fire floor. That is why staged and partial evacuations are standard in many tall buildings.

Prioritizing occupant access to elevators and stairs. Because elevators are a limited resource, they must be allocated to the evacuation of building occupants according to some sort of priority. In our analysis, the risk of occupants from fire is the major factor in allocating elevators -- the sooner occupants are likely to be endangered, the higher the priority they receive. However, other factors also play a role, for example, the need to vacate the floor below the fire so that it is quickly available as a fire department staging area.

Minimizing interference with the fire department. The evacuation plans discussed later in this chapter are designed, in part, to minimize interference with the operations of the fire department, even if it means that the evacuation is slowed somewhat. It is obvious that the fire department cannot respond efficiently to a fire if the stairways and elevators are not available when they are needed. Stairways and elevators are valuable and limited resources, and they must be carefully allocated between occupant use and fire department use.

In making this allocation, we can assume the call to the fire department and the initiation of the evacuation occur at approximately the same time. If the assumption is not valid, changes in the strategies may be needed. During the first few minutes of a fire emergency, the fire department will not yet be in a position to need either the stairways or the elevators -- it takes time for the fire department to receive and interpret the call, dispatch fire companies, drive to the fire, unload vital items off the trucks, enter the building, and determine a course of action (e.g., determine the highest floor below the fire from which they can stage operations). During those precious few minutes, selected occupants can use the stairs and elevators without interfering with the fire department -- **provided that they will have finished using these resources by the time that the fire department needs to use them.**

After the fire department arrives, it is unlikely to require the use of all stairs and elevators. Pre-fire planning by the fire department would be invaluable when planning which, if any, stairs and elevators are likely to still be available to evacuate building occupants. Obviously, the evacuation plan would need to be based on the availability of elevators and stairs.

THE ABILITIES OF *OCCUPANTS* TO USE STAIRS

Using elevators to evacuate occupants unable to use stairs. Some occupants will find it difficult, dangerous or physically impossible to descend or ascend stairs without assistance. This includes people in wheelchairs, as well as people with arthritis, orthopedic disorders (e.g., back and knee problems), and heart problems. If elevators are used to evacuate occupants during a fire, these persons should be moved vertically in the building using the safe elevators, even if all other occupants are directed to use the stairs. The fire safety strategy for these persons would be:

> Occupants unable to use stairs go to the elevator lobby where they will be evacuated using elevators.

Using elevators to relocate occupants able to descend floors. While evacuating persons unable to use stairs is the most obvious reason for using elevators in a fire emergency, an emergency plan might call for elevator evacuation for some occupants who are able to use stairs. The primary reasons are (1) to make full use of all available egress capacity and thereby completing the evacuation more quickly; (2) to help make stairways more available to firefighters; and, (3) avoid burdensome descents using stairs in very tall buildings.

Descending stairs to leave the building from the upper stories of very tall buildings is a daunting task for many persons without any disability. Many building occupants have marginal conditions that make descending many flights of stairs somewhat difficult, uncomfortable, or risky. Examples include persons who are pregnant, very old, and very young. When these occupants are not in immediate danger, they can report to the elevator lobby to be evacuated using safe elevators. When they are in immediate danger, they can use stairs to relocate to a safe floor below the fire and fire department staging floors. Once in this safe location, they can wait until elevators are available to take them to the ground floor.

Occupants on the lowest floors should not use elevators if they are able to use stairs. Lets assume that occupants on the second and third floors, who are able, will use stairs to evacuate before the fire department needs the stairways.

THE PROXIMITY OF *OCCUPANTS* TO THE FIRE

Occupants on the fire floor. Occupants on the fire floor are obviously the ones at most risk. The goal is to clear the floor as quickly as possible using both stairs and elevators. They should evacuate prior to the fire department arriving and commandeering some of the elevators and stairs. Occupants who cannot use stairs will stay to wait for elevators--they receive the "highest" priority for assigning fire safe elevators. We believe that a suitable set of strategies for the fire floor might be:

> Occupants on the fire floor who are unable to use stairs go to the elevator lobby to be evacuated using elevators. Occupants able to use stairs descend **two** flights below the lowest fire floor and report to the floor warden for further instructions.

If the fire is on the fifth floor, the occupants would *go* to the third floor. However, occupants who descend to the third floor **using** stairs would find the third floor being evacuated or already vacated. Instead of being directed to go to the third floor, they should be directed to leave the building, because once they have descended to the third or lower floor, it seems reasonable to continue out of the building.

Therefore the set of strategies for the fire floor might be expanded as stated below:

> Occupants on the fire floor who are unable to use stairs go to the elevator lobby to be evacuated using elevators. Occupants able to use stairs descend two flights below the lowest fire floor and report to the floor warden for further instructions. However, if the fire is below **the** sixth floor, occupants using the stairs should evacuate the building before the fire department amves.

Occupants just above the fire floor. Occupants on the floor above (and perhaps additional floors depending on the fire protection features of the building) could be quickly endangered. They should receive the second highest priority for access to elevators, second only to persons on the fire floor. The exact strategy for their movement might depend on the fire protection features of the building. In many office buildings, these occupants can travel upwards in the building to gain distance from the fire and to avoid having to travel directly past the fire. In buildings with sufficient horizontal compartmentation, occupants can safely travel downwards past the fire. These occupants might use the same set of strategies as occupants on the fire floor--except that their priority for accessing the elevators is lower.

Occupants just below the fire floor. Occupants on the floor immediately below the fire floor are relatively safe **from** the fire above. However, the fire department is likely to use this floor as its staging area. The occupants on this floor receive the third highest priority, because the floor should be vacated before the fire department arrives. They are possible candidates for evacuation by elevator--if there is enough time left over after evacuating higher priority occupants and before the fire department commandeers one or more elevators. Assuming there is sufficient time to evacuate all occupants from this floor by elevator before the fire department needs the elevators, a suitable strategy for the floor below the fire floor might be:

> All occupants go to the elevator lobby and evacuate using elevators.

Occupants two or more floors above the highest fire floor. These occupants are clearly in potential danger, but the threat is not immediate and hopefully the danger will not materialize. It may be desirable to have **all** the occupants on these floors wait for elevators, as this will alleviate crowding in the stairs **so** that they may be immediately used by fire fighters and by occupants in immediate danger. Once the fire department starts it attack on the fire, it is likely to be using most if not all of the stairways between the staging floor and the fire floor. If the occupants on these floors are assigned to use the elevators, they should receive the fourth highest priority for access to elevators. As an alternate approach, occupants on some of these floors could use the same strategy as occupants just one floor above the highest fire floor--except that their priority for accessing the elevators would be lower.

Occupants two or more floors below the lowest fire floor. These occupants are not in any clear danger, but would be expected to leave the building eventually if the fire emergency continues for any extensive period of time. They could use the same strategy as occupants on floors above the fire floors, except that they would receive the lowest priority for access to the elevators and stairs. However, it is likely that the fire department would be using some of the stairways only to move from the floor below the fire floor to the fire floor: some of the occupants several floors below the fire floor may be assigned to use the stairs that the fire department is using only to gain access to the fire floor from the floor immediately below.

The strategies for an entire building can be summarized in a one page table. Figure 2 on page 16, entitled POSSIBLE SET OF EVACUATION STRATEGIES, presents a complete set of strategies for all floors of an office building. The table may appear intimidating but each row can and should be considered separately for purposes of understanding the details of the table. The material in each row should not be difficult to comprehend. In fact, several of the rows were explained in the discussion immediately above.

This table and the associated set of strategies is presented as a basis for discussion. Actual sets **of** strategies should be tailored to specific buildings and tenants.

Notice that most occupants are not preassigned a specific mode of evacuation prior to the fire because the assignments and priorities depend on the location of the fire.

We have found that a wide variety of alternate sets of strategies can be summarized using the same table with only a few changes. For example, occupants on floors two through nine might be assigned to evacuate using the stairs. The strategies on the other floors would be the same as in Figure 2. This modified set of strategies is represented in Figure 3, FIRST ALTERNATIVE SET OF EVACUATION STRATEGIES, **where the only changes from the original table are underlined.**

Figure 4, SECOND ALTERNATIVE SET OF EVACUATION STRATEGIES, describes a variation that calls for immediate evacuation of the floor two floors above the fire floor. Changes from the initial table are underlined.

Figure 5, THIRD ALTERNATIVE SET OF EVACUATION STRATEGIES describes a variation that calls for those occupants on the two floors immediately above the fire floor, who can climb stairs, to .ascend to a higher floor.

Figure 6, FOURTH ALTERNATIVE SET OF EVACUATION STRATEGIES, introduces the concept that some occupants on upper floors, who do not need to use elevators, do use elevators and others use stairs. In an actual building, we would expect a more building specific criterion for which floors are selected for elevator evacuation than the simple rule that all occupants on even numbered floors use elevators.

These variations are presented to illustrate that there are many possible sets of strategies. Obviously, we have presented only a few. It is important to note that the comments and recommendations in this report apply to a large range of possible strategies.

Figure 2 - POSSIBLE SET OF EVACUATION STRATEGIES

LOCATION	STRATEGIES	ELEV. PRIORITY
First floor i.e., floor with exits at grade	All occupants use the nearest appropriate exit to leave the building.	not applicable
Fire floor (not first floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and go toward elevator lobby--unless the lowest fire floor is floor five or below in which case they evacuate the building.	highest priority
Floors two and three and also basements (not fire floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs evacuate the building. Occupants above second floor wait for permission before entering stairways.	low unless near fire
One floor below lowest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	very high
Two or more floors below lowest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	low
One floor above highest fire floor	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and go toward elevator lobby--unless the lowest fire floor is floor five or below in which case they evacuate the building.	second highest priority
Two or more floors above highest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	high

GENERAL APPROACH:

- Consider all floors with fire or smoke as fire floors.
- Evacuate all fire floors and adjacent floors as soon as possible.
- Direction of movement is always toward the first floor (ground floor.)
- Main assembly area for relocated occupants is two floors below the lowest fire floor.
- Occupants who can use stairs will evacuate the building by stairs whenever they are on floor three or below.
- Any floor that has proper and sufficient exit capacity can be considered a first floor or ground floor.

Figure 3 - FIRST ALTERNATE SET OF EVACUATION STRATEGIES

LOCATION	STRATEGIES	ELEV. PRIORITY
First floor i.e., floor with exits at grade	All occupants use the nearest appropriate exit to leave the building.	not applicable
Fire floor (not first floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and go toward elevator lobby--unless the lowest fire floor is floor eleven or below in which case they evacuate the building.	highest priority
Floors two thru nine and also basements (not fire floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs evacuate the building. Occupants above second floor wait for permission before entering stairways.	low unless near fire
One floor below lowest fire floor (if floor ten and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	very high
Two or more floors below lowest fire floor (if floor ten and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	low
One floor above highest fire floor	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and go toward elevator lobby--unless the lowest fire floor is floor eleven or below in which case they evacuate the building.	second highest priority
Two or more floors above highest fire floor (if floor ten and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	high

GENERAL APPROACH:

- Consider all floors with fire or smoke as fire floors.
- Evacuate all fire floors and adjacent floors as soon as possible.
- Direction of movement is always toward the first floor (ground floor.)
- Main assembly area for relocated occupants is two floors below the lowest fire floor.
- Occupants who can use stairs will evacuate the building by stairs whenever they are on floor nine or below.
- Any floor that has proper and sufficient exit capacity can be considered a first floor or ground floor.

Figure 4 - SECOND ALTERNATE SET OF EVACUATION STRATEGIES

LOCATION	STRATEGIES	ELEV. PRIORITY
First floor i.e., floor with exits at grade	All occupants use the nearest appropriate exit to leave the building.	not applicable
Fire floor (not first floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and go toward elevator lobby--unless the lowest fire floor is floor five or below in which case they evacuate the building.	highest **priority**
Floors two and three and also basements (not fife floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs evacuate the building. Occupants above second floor wait for permission before entering stairways.	low unless near fire
One floor below lowest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	very high
Two or more floors below lowest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	low
One or two floors above highest fire floor	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and go toward elevator lobby--unless the lowest fire floor is floor fiie or below in which case they evacuate the building.	second highest priority
Three or more floors above highest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	high

GENERAL APPROACH:

- Consider all floors with fire or smoke as fire floors.
- Evacuate all fire floors and adjacent floors (one below and two above) as **soon** as possible.
- Direction of movement is always toward the first floor (ground floor.)
- Main assembly area for relocated occupants is two floors below the lowest fire floor.
- Occupants who can use stairs will evacuate the building by stairs whenever they are on floor three or below.
- Any floor that has proper and sufficient exit capacity can be considered a first floor or ground floor.

Figure 5 - THIRD ALTERNATE SET OF EVACUATION STRATEGIES

LOCATION	STRATEGIES	ELEV. PRIORITY
First floor i.e., floor with exits at grade	All occupants use the nearest appropriate exit to leave the building.	not applicable
Fire floor (not first floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and go toward elevator lobby--unless the lowest fire floor is floor five or below in which case they evacuate the building.	highest **priority**
Floors two and three and also basements (not fire floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs evacuate the building. Occupants above second floor wait for permission before entering stairways.	low unless **near fire**
One floor below lowest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	very high
Two or more floors below lowest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	low
One <u>or two floors</u> above highest fire floor	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs <u>ascend to three floors above highest</u> fire floor and go toward elevator lobby....	second highest priority
<u>Three</u> or more floors above highest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	**high**

GENERAL APPROACH:

- Consider all floors with fire or smoke as fire floors.
- Evacuate all fire floors and adjacent floors (<u>one below and two above</u>) as soon as possible.
- <u>Initial vertical direction of movement by stairs is always away from the fire floor.</u>
- Main assembly area for relocated occupants is two floors away from the nearest fire floor.
- Occupants who can use stairs will evacuate the building by stairs whenever they are on floor three or below.
- Any floor that has proper and sufficient exit capacity can be considered a first floor or ground floor.
- <u>No special rush to evacuate occupants above the fire from the building.</u>

Figure 6 - FOURTH ALTERNATE SET OF EVACUATION STRATEGIES

LOCATION	STRATEGIES	ELEV. PRIORITY
First floor i.e., floor with exits at grade	All occupants use the nearest appropriate exit to leave the building.	not applicable
Fire floor (not first floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and...follow instructions for that floor–unless the lowest fire floor is floor five or below in which case they evacuate the building.	highest priority
Floors two and three and also basements (not fire floor)	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs evacuate the building. Occupants above second floor wait for permission before entering stairways.	low unless near fiie
One floor below lowest fire floor (if floor four and above)	All occupants go toward elevator lobby. Occupants are evacuated using elevators.	very high
Two or more floors below lowest fire floor (if floor four and above)	All occupants on even numbered floors go toward elevator lobby. Occupants are evacuated using elevators. On odd numbered floors occupants unable to use stairs go to elevator lobby. Others go toward designated stairways and await instructions to evacuate.	low
One floor above highest fire floor	Occupants unable to use stairs go to elevator lobby. Occupants in elevator lobby are evacuated using elevators. Occupants able to use stairs descend two flights below lowest fire floor and...follow instructions for occupants of that floor–unless the lowest fire floor is floor five or below in which case they evacuate the building.	second highest priority
Two or more floors above highest fire floor (if floor four and above)	All occupants on even numbered floors go toward elevator lobby. Occupants are evacuated using elevators. On odd numbered floors Occupants unable to use stairs go to elevator lobbv. Others go toward designated stairways and await instructions to evacuate.	high

GENERAL APPROACH:

- Consider all floors with fire or smoke as fire floors.
- Evacuate all fire floors and adjacent floors as soon as possible.
- Occupants who are above the third floor and not near the fire floor will use elevators if they are on an odd numbered floor or if they cannot use stairways. Otherwise, they wait near stairways for their turn to enter the stairwav.
- Main assembly area for relocated occupants is two floors below the lowest fire floor.
- Any floor that has proper and sufficient exit capacity can be considered a first floor or ground floor.

COORDINATING AND DIRECTING THE EVACUATION

During a fire incident, decisions must be made about which floors will be evacuated before others. The task of routing elevators to floors can be complex and must be directed and coordinated from a central location. Congestion on the stairs can be kept to a reasonable level by a phased evacuation into the stairwells. Several factors can be considered when setting priorities for evacuating occupants from different floors. Varying degrees of automation are possible, but some human oversight over the elevator evacuation is probably essential to assure reliability in view of the unpredictability of fire scenarios. Also, the control of the flow of occupants into the stairwells would require the participation of the emergency team.

MANUALLY VS. AUTOMATICALLY DIRECTED EVACUATIONS

While varying degrees of automation are possible, we will examine only two feasible anchor-points along the continuum: evacuations that are coordinated entirely by coordinators and evacuations that are directed by a computer program with oversight by coordinators. (Persons in the control room who are responsible for the direction of the elevators are labelled "coordinators," regardless of whether they are fire fighters or building employees.)

Manual control. The first approach is to have persons in the command center direct elevators to where they are most immediately needed and to alert stairway monitors when their floor should be evacuated. Operators would be stationed in the elevators. The coordinators would communicate with and direct these operators. A decision protocol or evacuation model should be developed to assist coordinators in prioritizing floors.

Automated control with human oversight. The second approach is to use a computer program to set priorities, send elevators to the appropriate floor, and determine which floors should be evacuating into the stairwells. Two sources of input used together would provide much of the information that would be used in prioritizing the routing of elevators to floors: (1) the alarm system identifies the fire floor or zone, and (2) the call buttons that occupants customarily use to request elevator service identify which floors have building occupants waiting to be evacuated. Depending on the evacuation decision rules, additional input could be provided by coordinators (e.g., how many people are waiting in particular elevator lobbies). The input for controlling the phased stairwell evacuation would be information provided by floor and stairway monitors. We also assume that monitors would **not** be assigned to operate elevators. However, to assure an acceptably high level of reliability, we assume that some sort of human oversight over the operation of the computer program will be needed. Coordinators would monitor the activities of the computer as well as the fire conditions in the building. If necessary, they could override the computer and either: (1) monitors would commandeer the elevators and operate them or (2) the coordinators would directly control the elevators from the control room.

COMPARISON OF MANUAL AND AUTOMATED CONTROL OF ELEVATOR EVACUATION

In the following paragraphs, we compare and contrast the two approaches using several criteria. The following discussion contrasts the two extremes of maximum automation with human oversight, and minimum automation. If fire safe elevators are installed in buildings, we would not be surprised or disappointed if a compromise or hybrid system were installed, such as computer control of the elevators with operators on the elevators who have some power to ovemde the computer controls.

An automated system can better handle the complexity of contingent strategies. As discussed in the section on strategies, an approach that considers the interaction between building height and the location of a fire would employ several strategies. Different strategies would be assigned to a floor depending on whether it is an upper story and whether it is in, above, or below the fire zone as was illustrated in the chapter, **SELECTION OF STRATEGIES.** Furthermore, the assignment of destinations for the next elevator run would depend on fire growth and the number of occupants in elevator lobbies. Assembling and training the cadre of coordinators needed to manually operate such an approach might be well beyond the resources of all but the largest building and the motivation of all but the most dedicated of building owners and managers. The level of complexity would tax coordinators' abilities to process information. Perhaps full or partial automation is the only pragmatic approach. The computer program might prioritize and send elevators to floors, as well as initiate the transmission of relevant pre-recorded verbal messages.

Under expected conditions, manning requirements would be less using an automated approach. The manual control of elevators requires more trained building employees than an automated control, especially if elevators are operated by building employees. In a fully automated system, not only would the elevator operators not be needed, but fewer coordinators would be needed to man the control room as well. **However, if coordinators must be prepared to take over all the functions normally operated by the computer (e.g., the computer "crashes"), then the manning requirements would not differ between the approaches.**

An automated approach can be initiated much more quickly. Automated control could be initiated immediately upon receipt of an alarm. Manual control would likely take significantly longer, especially if elevator operators must travel to the elevators, commandeer them, and await instructions from the control center. Of particular concern is the location at which the elevators can be commandeered. A typical elevator capture delivers the elevators to the ground floor to discharge passengers, but trained building employees might be at remote locations in the building. It might be possible to deliver the elevators to the operators, but this entails considerable added complexity.

Human oversight may be essential to a reliable automated approach. The issue of reliability is complicated but of great importance. The issue can be divided into two different types of reliability: faultiness (does the system fail to perform as designed) and adaptability (can the system compensate for problems). The relative reliabilities are shown in the following table.

Figure **7 -** COMPARISON OF AUTOMATED AND MANUAL **CONTROL** OF ELEVATOR EVACUATION

	faultiness	**adaptability**
automated control	Faultiness results from three primary sources; failure of hardware components, disruption of the communication system, and "bugs" in the computer program. Faulty hardware components are likely unless supervisory circuits protect program inputs (e.g. fire detectors) and outputs (e.g. circuits to public address speakers) and a vigorous program of testing and maintenance have been installed. Communication links and power supplies should be "hardened." Bugs can be limited by careful programming and testing.	The degree of adaptability depends directly on the abilities of the systems analysts and programmers to develop a computer program that applies to a wide range of fire scenarios and that responds to changes in data inputs. However, fire scenarios in buildings are difficult to predict accurately, largely because of unanticipated problems in the building itself. Thus, an automated approaches probably requires vigilant supervision by coordinators who can redirect elevators in response to a dynamic incident.
manual control	Faultiness results from three primary sources; failure of hardware components, disruption of the communication system, and human error. Human error depends heavily on the quality of training received by coordinators and the relevance of the data provided to them. The human factors of hardware also play an important role. For example, the quality of displays influences the probability that coordinators will misinterpret or miss key information.	People in responsible positions usually respond effectively to changing situations if they have sufficient and relevant training and adequate information. ***Also,*** they must not have an over-whelming level of stress or information overload.

Cognitive demands (information processing loads and vigilance) on coordinators differ between the two approaches. During expected operating conditions, the character of the cognitive tasks on coordinators differs significantly between the two approaches. In manual control, coordinators make decisions that direct the course of the evacuation. There is a high threat of information overload. The coordinators must obtain information about conditions in the building, available resources, and the progress of the evacuation. They must then process the meaning of that information, decide when and where to direct elevators, and transmit those instructions. The cognitive demands can be considerable. If task demands are too great, then coordinators will compensate in order to keep the task manageable. They might be forced to ignore potentially important infomation or to neglect more peripheral tasks. They may reach decisions too hastily. Since mistakes can have serious consequences, we recommend that a program of research be directed at the problem of information overload. The project should study how to provide vital information and still ensure that decision rules, information displays, task allocations, and communications management are designed to keep cognitive demands on individuals at a manageable level. This research program should provide needed input into training programs,

The cognitive demands on control room coordinators are quite different using an automated system — provided that they do not need to override any of the programmed functions. The coordinators necessarily assume one primary task they observe the evacuation to ensure that elevators are sent to rescue persons in relatively greater jeopardy, but are not sent into untenable conditions or to locations that have been evacuated by other means. Their primary task is one of vigilance. Because coordinators are mostly observing, their concentration can waiver. An even greater danger is that they will be removed or distracted from their task by other demands in the control center. This latter threat can be mostly eliminated by sufficient manning and by ensuring that the incident commander understands that coordinators must remain dedicated to the oversight task. Although they normally only observe the operation of the automated system, the coordinators must be prepared to take over the routing of elevators in the event that (1) there are hardware failures, or (2) the fire threat or tenability conditions require a change from the routing called up by automated software control.

The coordinators should compile data that is not obtained electronically and enter the data into the computer. For example, the computer program may need to know the numbers of persons awaiting rescue in elevator lobbies as reported by elevator monitors. There are two reasons that the coordinators might be required to perform this task. Using the coordinators is an efficient and simple way of entering data into the computer. Also, it gives the coordinators a non passive task in addition to their more passive role of oversight. If the controllers need to ovemde the automatic procedures, being more actively involved will help make the transition more effective.

Training will be similar for both approaches, although machine interfaces may be very different. If coordinators need to override all or parts of a program, the data needs and the decisions to be made should resemble those performed by persons coordinating a manually-directed evacuation, but with an important difference. The human-machine interface might differ greatly between the two approaches, because overriding the program is likely to involve interacting with the computer, another area requiring careful study and analysis. Coordinators must be trained to recognize situations based on available data and respond accordingly using a previously selected set of decision rules. (These rules are likely to closely resemble the rules upon which a computer program is based.)

However, certain aspects of the training programs would diverge because coordinators must be totally familiar with the machine interfaces with which they interact.

As the complexity of the task allocations increases, successful operations will be increasingly dependent on team work. Training will require coordinators to practice operations together. This becomes even more vital where fire fighters and building employees work cooperatively.

DEVELOPING AN EVACUATION COORDINATION MODEL

Regardless of whether an automated or manual approach is used, there is a need to develop a model or set of decision rules that would prioritize floors for evacuation and route elevators to them. The rules need to be responsive to the dynamic nature of a fire emergency. Any of the following types of infomation might affect the application of these decision rules: (1) the availability of resources, that is, the number, capacity, and speed of elevators; (2) the number of persons waiting to be evacuated at each elevator lobby; (3) the availability of alternative strategies for those persons; (4) the degree of risk to which the occupants in each elevator lobby are exposed; and, (5) the likelihood that sending an elevator to a particular floor might damage the elevator so that it can no longer be used safely and efficiently.

We believe that the decision rules should be based on recommendations of an expert panel, comprised of experts on fire protection engineering, building management, fire fighting, and psychology.

INFORMATION NEEDS OF AND DECISION-MAKING BY CONTROL CENTER

During a serious fire, coordinators may be making life-and-death decisions. For this reason, it is essential to anticipate the types of decisions and the information needed to make those decisions. The decision rules, and the information necessary to satisfactorily implement these rules, will depend on the specific characteristics of the building and its occupants. Nevertheless, we can anticipate some decision rules that are likely to be used frequently and some types of information that will frequently be required.

Since a coordinator may need to take over the routing functions of an automated system, most of the decisions are common to the automated and manual-controlled approaches. There is an added decision to the automated approach. The coordinator may need to decide at what point to override automated elevator calls, or, in the event of a partial failure of the automated system, to completely preempt the computer program.

The following table shows some sample decisions along with the types of information that might be needed to support those decisions.

Figure 8 - INFORMATION NEEDS OF AND DECISION-MAKING BY CONTROL CENTER

DECISION	NEEDED INFORMATION
Are conditions so severe on a floor that the elevator should not be sent there?	1. Smoke obscuration in elevator lobby. 2. High temperatures or flames in elevator lobby that might damage elevators. 3. Reports of any persons trapped on floor waiting for elevator. 4. Availability of rescuers to operate elevator.
What is the priority for sending elevators to floors?	1. Proximity of floor to fire zone. 2. Presence of smoke on floor. 3. Possibility that other elevators or building areas might be exposed as well. 4. Total number of persons in elevator lobbies waiting for elevators. 5. Number of persons in elevator lobbies waiting for elevator who cannot use stairs. 6. Height in building of floor.
Should the automatic-operation of elevators be overridden?	1. The program's operation seems inconsistent with the coordinator's perception of floor priorities (e.g., people are in danger but their floor is not assigned the highest priority). 2. There is an indication of a hardware fault. 3. Floors remain in the queue although they have been successfully evacuated.

COMMUNICATIONS BETWEEN FLOORS AND THE CONTROL CENTER

As noted in the previous section, coordinators should probably know: (1) the types and numbers of people located on each floor, prior to the fire, and (2) the types and numbers of people waiting for the elevator, on a continuing basis. The information should include infomation regarding occupants who either cannot descend the stairs, or cannot descend stairs without pain or without a health risk.

Telephone and intercoms are a means to obtain current information from floors. Persons in elevator lobbies are vital sources for information. (As discussed later in this report, it is also important that persons on floors obtain information from coordinators.) Much was learned about the relative merits of various devices from the study of staging areas. Telephone receivers have the following advantages: they partially block out background noises, which can be critical where fire alarms are loud, and their operation is generally more familiar to people. However, intercoms also have important advantages: they can double as public address systems, allowing the broadcast of simultaneous messages to all elevator lobbies. Also, messages can be relayed easily to many people at multiple locations. However, all voice communication devices have an important disadvantage: the amount of time needed to assemble information from various people can be considerable in a large building.

Nonverbal input devices could be used to quickly obtain specific information from monitors in elevator lobbies. Keypads, keyboards, or consoles could be installed in elevator lobbies. They could be used by trained monitors from different floors to simultaneously transmit important information to the control room. An example of such a device is an elevator call button. The button provides little information. It could be replaced by a device that also indicates the numbers of people waiting as well, or, if everyone leaves the area, the device could be used to cancel the call. Trained emergency team members would probably be needed to operate such devices, but most emergency plans are likely to require their presence in elevator lobbies, prior to complete evacuation of the floor, anyway. Unless the user interface is very "user friendly", emergency team members will require training to use these devices.

A video system can be used to quickly assess conditions in elevators lobbies. Using a security-type video system to quickly assess and monitor elevator lobbies could prove invaluable to coordinators. Similar to the use of consoles, it has the advantage of speed, but without being dependent on someone entering data, accurately and in a timely fashion. In addition to providing information prior to and during the elevator assisted evacuation of a floor, the video system could be used for any of the following functions: (1) validate reports that persons are in elevator lobbies that were previously evacuated; (2) locate persons who arrive after a lobby has been evacuated; and (3) monitor smoke intrusion into lobbies.

Tracking the progress of the evacuation. In a larger building, coordinators must be able to immediately determine the exact progress of an evacuation. They must know which floors have been evacuated, which floors have not, the numbers and types of persons awaiting evacuation on specific floors, and the presence of any fire signs on occupied floors, elevator lobbies and stairwells. The total information load is probably too great for coordinators to dependably keep track of "in their heads." Needed help could be provided with varying degrees of automation. In a completely manual system, one individual could be dedicated to the task of monitoring and displaying this information, perhaps using a blackboard. A completely automated system could display the actions planned by the computer program and the presumed status of the evacuation. The information could be displayed on a CRT or annunciator-type panel. Regardless, the information should be displayed using a graphical approach, preferably using a vertical layout of the building.

PROTECTING AGAINST FAILURE IN CONTROL ROOMS

For the most part, our analysis assumes that hardware components will be mostly reliable. Some reliability issues are discussed elsewhere in this section. However, large-scale failures in the control room are important enough to warrant a separate discussion. Obviously, if there is a backup control room with a backup computer, reliability will be increased; this option need not be further discussed.

A system might function at a reduced level of performance without the control mom. The control room is the "brain" of the evacuation effort, so the reliability of receiving inputs and transmitting outputs is important. But a prior question is whether a hardware failure in the control room is catastrophic or whether the system can operate at some level of performance without centralized control. We can assume that emergency team members in elevator lobbies will attempt to take some course of action. It might be possible to devise a system that would allow remote locations to control elevators without mediation from the control room or computer, albeit with some loss of reliability, efficiency, or both.

Installing the computer and the control room in locations remote from each other might increase reliability. Physically locating the computer in an area remote from the control room, would affect the reliability of an automatically-controlled system. The added link between the computer and control room (and possibly between the computer and the elevator controls) increases the probability that some part of the system will fail. However, in the event that communication between either the computer or the control room and the elevator lobbies is severed, some centralized control over the evacuation could still be maintained if the problem is any one of the following: (1) the control room becomes uninhabitable or inoperable; (2) the computer fails; (3) communication links between the control room and elevator lobbies fail; or (4) communication links between the computer and the elevators and elevator lobbies fail. (This assumes that there is a communication link to the elevators and their lobbies directly from both the computer and the control room.) Provided that the link between the computer and control room is well-protected, this approach could result in an increase in reliability.

CRITERIA FOR LOCATING CONTROL ROOMS

Control rooms serve vital functions during a fire emergency, even more so when they serve as the location for coordinating a complex set of strategies. The authors' study of staging areas revealed that control rooms were often located and staffed without considering some important criteria. These criteria are listed as follows:

The location should be accessible to both the fire department and building employees. The control room should be in an area that can be easily reached by both the fire department and building employees. The same interior location where the fire department would want to establish its command post should be a good choice so that all operations can be centralized. Locations in or near entrance foyers and lobbies of office buildings are often logical choices. The practice of locating control rooms in basements should be reconsidered.

The location should be protected from immediate involvement in a likely fire scenario. The control room should not be located adjacent to fire hazards or where a fire could block access or escape.

The *size* should be sufficient to accommodate everyone with a role along with all the needed hardware. In our study of staging areas, the terminus for staging room communications was sometimes located in a room that was too small for more than a few people. A control system designed for use in elevator evacuations would likely require more personnel and more equipment.

The location should be quiet enough to permit conversations and use of communications equipment. Our study of refuge areas revealed that command centers were often installed in security offices. These rooms were often equipped with fire alarm bells that were so loud that they precluded normal conversation and prevented communication via telephones or radio. In some instances, the occupants were unable or unauthorized to deactivate these signalling devices.

Communications between the control room and elevator lobbies should be available whenever the building is occupied. Our staging area study revealed the problem that control rooms were sometimes located away from security offices or other areas that are always manned. It is desirable to locate control rooms in areas always occupied. However, considerations of protection and fire department access probably are more important, because coordinators can always report to a control room that is otherwise unmanned. In this situation, building occupants should be aware that elevator lobby communications devices are not a means to report fires (a manual pull station should be installed nearby), and that a brief delay might be experienced during a fire emergency.

In smaller office buildings, the control room may not be occupied after working hours. In some of our studied buildings, staging area communications were routed off-site to deal with this situation. However, the added link makes quick and accurate communications between the command center and building locations problematic. We will not pursue this possibility in this report because the initial installations of fire safe elevators are likely to be in buildings that would have a security staff on duty in the building at all times.

MANNING CONTROL ROOMS

Job qualifications. Coordinators should be recruited and selected with specific tasks in mind. The technology of analyzing tasks to determine job qualifications is well-developed. Our best guess about the type of skills needed include the following:

Analytical skills: the ability to analyze information for the purpose of making decisions is a required skill. A prescribed level of academic accomplishment is probably not needed. Tests designed to predict future academic performance are not relevant. To some extent these analytical skills will be developed during training and to some extent the need for these skills will be minimized by decision rules taught during training.

Social skills: coordinators must be able to work as a team. During an emergency, coordinators will need to adhere to some sort of command structure, because the time needed to cooperatively make decisions will not be available.

Language skills: Communications is an essential function for coordinators. They must communicate with each other. Even better language skills are required to speak over telephones, the public address system, or similar equipment where clear articulation and concise phrasing are required. Excellent English language skills will be required of coordinators who communicate with remote building locations. Skills in other languages may be very desirable depending on the national origins and English language proficiencies of persons normally occupying the building. It is not the size of the vocabulary that is important, it is the skill in using simple language that counts.

Effective interactions between building officials and the fire department. We anticipate that regardless of who fills the coordinator roles, overall command of the incident will pass from the ranking building official to the senior fire department official, **i.e.,** incident commander. This transition is critical. If the incident commander is totally unfamiliar with the elevator evacuation, doesn't "believe" in elevator evacuations, or simply disregards the ongoing operation, a dangerous level of confusion may result.

The following measures should mitigate the possibility of a unsafe transfer of authority to the fire department.

The building employees must be prepared to fully brief the incident commander, and the incident commander must be receptive to the briefing. The fire department must "buy into" the concept of an elevator evacuation. Cooperation of and support by the fire department should be sought during the design stage, prior to building or retrofitting the building. **Failure to obtain support and cooperation from the fire department may be sufficient reason to abandon the fire safe elevator approach in that community.** Since it is "common knowledge" that elevators are unsafe during fires incidents, the fire department's pre-fire planning process should thoroughly acquaint them with the feasibility of the system. They should be aware of safeguards, both hardware and procedural, designed to ensure a high degree of safety and reliability.

There should be a smooth transfer of control to the fire department. This means that the building official must willingly relinquish control. The building official would hopefully either continue in an advisory capacity or be assigned the role of continuing the direction and coordination of the evacuation.

Fire departments should allow key building employees to continue in their roles. Coordinators should be allowed to retain their positions while the fire fighters undertake other tasks such as suppression and search and rescue. It is unlikely that fire fighters will have the specialized training to replace coordinators. If they have received the training, there would still be a temporary loss of time.

CARRYING OUT THE EVACUATION

In the previous section, we discussed the coordination and direction of elevator evacuations. In this section, our attention turns to the object of that coordination — the people who are evacuated, including both a building's emergency team (e.g., monitors, floor wardens) and its occupants at large. A major thrust of this report is determining those conditions and measures that will increase the chances that most occupants will follow the fire emergency plan.

FACTORS AFFECTING COMPLIANCE WITH THE EMERGENCY PLAN

Impact of psychological control. Humans have strong psychological needs to exert some control over their own fate. This well-known need is so strong that people imagine an ability to influence outcomes over which they really have no real control. When evacuating by elevator, a person is permitting his safety to depend on a mechanical device and on the building staff (or computer) that controls the staged evacuation and the scheduling of the elevators.

The emergency coordinator may know the safest course of action. When this course of action is the obviously safest strategy, then occupants are likely to follow instructions. But when the safest strategy is not obvious or intuitive, the emergency planner would be naive to expect building occupants to simply comply with his or her recommendations. Instead of passively following instructions, many people will choose actions that they believe provide them with a higher degree of safety. A good emergency plan will provide enough information to reassure occupants that building management has devised the best approach for themselves and other building occupants. Only then will occupants willingly accept recommendations from building officials.

In general, we expect that many people will prefer to take actions to assure their own safety rather than be dependent on others or on mechanical equipment such as elevators. If the number of floors to descend (or ascend) does not appear onerous, we hypothesize that most healthy mobile young adults will prefer to use the stairs.

Willingness of individuals to consider safety of others. Studies of behavior during actual fire emergency situations have shown that social norms are not generally abandoned, and people do care for and assist one another. (Sime, 1990) However, fear and the desire to avoid pain, injury and death are great motivators and will affect the decisions of the occupants. Normally, people will follow a fire plan only if they believe that it will provide them personally with safety. We believe most people will accept a small degradation in their personal safety if they believe that their level of safety remains very high--so high that they do not consider themselves in danger--and that they are contributing to the safety of others. Therefore, we would anticipate that occupants will willingly wait their turn to use the elevator or stairs if they believe that they still would be able to safely evacuate and the delay permits an orderly evacuation for all and a more rapid evacuation for those closer to the fire.

The authors are aware of reports that people in nightclubs have waited in line to use an exit just prior to flashover; that is, they permitted others, whom they could see, to escape when they, themselves, could not. They could see that their sacrifice would not be in vain and any attempt to increase their own safety most likely would doom all, including themselves. The authors do not believe that people will passively accept a significant increase in danger in the hope of increasing the safety of unknown people in a remote part of the building; that is, **they will** not **wait for the elevator and defer using tbe stairs if they have significant doubts about their own safety.**

Altering previous learning. Years of training to *not* use elevators during fires is surmountable. Human cognition supports adaptability. People fly using airplanes and breath underwater using breathing apparatus. Beliefs such as "people can't fly," "people can't breath underwater," and "elevators aren't safe during fires" can be changed by rational argument and experience. People can be taught to use elevators in buildings where it is safe, and to avoid their use in other buildings. It is probably helpful that there is a general tendency for people to use the same path to leave a building as they use to enter it. Therefore, there is a natural tendency to use the elevator.

Anxiety levels of people. There may be in the building some few individuals with intense anxiety about elevators and/or fires who would not participate in their use. For the remaining individuals, anxiety feelings and tolerance for crowding during a waiting period will vary. Occupants may be instructed to wait for up to one-half hour or more in a crowded elevator lobby before elevators start arriving at their assigned elevator lobby. (Analyses of specific buildings by Klote, et al, (1992) indicate a ten minute maximum if both stairs and elevators are used. However, the data presented by Bazjanac (1977) and Galbreath (1969) suggest that a wait of 30 minutes or more could occur.) The "inaction" of waiting for elevators is not intuitive and would involve feelings of loss of control and anxiety.

It is impossible to avoid anxieties but good communications with the control room should help keep them to a tolerable level. All occupants waiting in an elevator lobby must be in frequent contact with the control room, such as directly through public address announcements or indirectly through floor monitors who have frequent telephone contact. They should be informed of the progress of the fire, firefighting activities, progress of the evacuation, and the expected time before elevators will start to arrive.

Credibility of the content of the emergency plan. The fire plan and the fire safety features of the building must, in fact, provide a very high level of safety. Further, enough information must be conveyed to occupants for them to fully understand the value and logic of the plan. People will follow a plan if they believe that it reduces their risk and the risks to other building occupants.

In our study of staging areas, we found that people who knew little about the protection features of staging areas were very skeptical about the safety provided. However, after having been informed about the safeguards, they usually warmed noticeably to the approach.

We believe that considerable, easy-to-understand information about the safety features of life safety systems should be made available to all building occupants. Many persons targeted to use elevators will take a keen interest in this information. Even if they have no reasonable alternative but to use the elevators (e.g., the stairs are blocked or they are on the 80th floor), the information will significantly increase their psychological comfort.

It is also important that the occupants understand why some of the alternative--and possibly more intuitively obvious--strategies might cause problems that would decrease safety, e.g., evacuating by stairs might interfere with firefighters using the stairs. This information should be in the written fire plan distributed to each employee and covered in a mandatory training program.

The fire plans must be continually updated. Out of date plans will indicate that management is not on top of those responsibilities that can be observed and evaluated by the building occupants. There would be little confidence that management is doing a better job on those aspects of its responsibilities that cannot be evaluated.

When new tenants move into an office building, it is a period of turmoil and confusion. Special effort must be taken to have an acceptable and workable fire plan in effect during this period, even if it requires the effort and expense of developing a special interim plan. If employees see that their bosses have not carefully provided for their safety during this period, it may take years of effort to convince them that a complicated fire plan using elevators can be trusted.

Credibility of management (the source of the emergency plan). People will not be able to judge directly if the plan provides safety for them. The credibility of the source has a strong impact on persons' willingness to believe the message. If people have faith in building management, they will follow instructions that appear reasonable.

Credibility of the coordinator. There is also a need for credibility of the person actually communicating instructions during an emergency. In general, fire department officials will enjoy a greater level of credibility because of their perceived level of expertise. A coordinator who explains that his recommendations are based on current conditions will enjoy greater credibility than someone who recommends actions based on an inflexible emergency plan.

In most buildings, occupants have little direct contact with building management. Rather, other factors will limit the credibility of building management, including, but not limited to the following:

- The degree of involvement by the fire department or other fire safety experts in the development of the emergency plan.
- The quality of relationships between the building management and tenant organizations (e.g., disputes about issues unrelated to fire safety can interfere with cooperation when implementing the emergency plan).
- The quality and maintenance of building features not directly associated with fire safety (e.g., problems with security or climate control in the building).
- The quality of written fire safety materials distributed to building occupants (e.g., the plan is confusing).
- The quality of the training received by emergency team members (e.g., elevator lobby monitors don't fully understand procedures).

- The quality of training received by occupants at large (e.g., building management has not briefed occupants about new procedures before running a drill).

- Apparent problems with the maintenance of fire safety features (e.g., frequency of false alarms).

Familiarity. Information about the system is not sufficient. People should become familiar with their required actions by actually performing them in a simulated fire situation. This is commonly called a fire drill and is discussed below. Actually performing the required actions will increase understanding and should make the actions feel less "strange" or counter intuitive. In addition, some of this information can be conveyed during the training sessions; for example, occupants can be shown the control room and some of its communications equipment.

INFORMATION NEEDS OF AND DECISION-MAKING BY MONITORS AND OCCUPANTS

Decision-making by emergency team members. The fire emergency plan coupled with instructions from the command center should provide fire emergency team members with a recommended course of action. Nonetheless, emergency team members (e.g., elevator monitors) do make important decisions. Even the behavior of complying with the emergency plan involves the decision to do so. They have the power, with or without permission, to recommend an alternative strategy when they believe it is necessary. For example, a monitor might decide that the wait for an elevator is getting too long, and recommend that anyone who is physically able should evacuate using the stairs.

Decision-making by occupants at large. Building occupants without emergency team roles make similar decisions. They can comply with recommendations or they can follow some other course of action that they believe provides greater safety. For example, a person without any disability could decide that the walk down stairs would be too exhausting and instead wait for the elevators along with persons unable to use the stairs.

The information needed to make good decisions must be anticipated. In a large building, the data needed to make good decisions is not available first hand. People have no way of directly learning about conditions elsewhere in the building. Anticipating these needs for data and information will be vital to the development of the best possible decision protocols, task descriptions (needed to select and train emergency team members), and human-machine interfaces. While the specific detailed information that is needed will vary form building to building, we can anticipate some of the commonly required information.

The following table shows some sample decisions along with the types of information that might be needed to support those decisions. The specific decisions and infomation needs will vary depending on the set of strategies used, the building characteristics and the fire safety features in the building.

Figure 9 - INFORMATION NEEDS AND DECISION-MAKING
BY MONITORS AND OCCUPANTS

DECISION	NEEDED INFORMATION
Some persons who are able to descend stairs are directed to use elevators. Should they wait for the elevator or abandon the elevator lobby?	1. The waiting time before an elevator is scheduled to arrive. 2. The probability that the elevator lobby will become unsafe, and how soon. 3. The current and future congestion on stairs. 4. The probability that stairs will become unsafe, and how soon. 5. The probability that areas that must be traversed to reach the stairs will become unsafe, and how soon.
Should persons unable to descend stairs be taken down stairs to a safer floor?	ALL OF THE ABOVE PLUS... 1. The risk of injury to those persons who can descend stairs if absolutely necessary. 2. The availability of persons who can help carry people down stairs. 3. The training of persons who can help carry people down stairs. 4. Fragility of each person who needs to be carried.
Should persons unable to descend stairs be taken to an area other than the elevator lobby?	ALL OF THE ABOVE PLUS... 1. The existence and relative safety of other rooms and areas on the same floor. 2. The probability that areas that must be traversed to reach these relatively safer areas will become unsafe, and how soon.

COMMUNICATIONS BETWEEN FLOORS AND THE CONTROL CENTER

Elevator lobby occupants need an overview of the status of the incident. The control center needs to relay as well as receive information. (The information needs of the control center are discussed in the chapter COORDINATING AND DIRECTING THE EVACUATION.) Without information about the status of the incident, elevator lobby occupants are more likely to make poor decisions such as unnecessarily abandoning the lobby area. Moreover, reducing the ambiguity of the situation will increase their psychological comfort.

Providing information will not increase the probability that elevator lobby occupants will panic. Some fire safety experts recommend against providing information to building occupants on the theory that occupants might "panic." (We are defining "panic" as behaving in an plainly counterproductive manner given the information available to the person.) They reason that occupants won't panic if they don't know the extent of a fire, or even if one exists. However, extensive research has shown that there is little threat of panic behavior. Panic during fires is very rare, and then perhaps occurs only when people perceive that they are trapped and may be unable to escape from the impending threat. (Quarentelli, 1977) Assuming that the fire safety features and fire protection systems in the building plus the fire plan does, in fact, provide a high level of safety, then accurate information should diminish any fears of entrapment or of an inability to eventually evacuate the building.

Moreover, withholding infomation probably increases anxiety by increasing ambiguity. Ambiguity denies building occupants a sense of control. Control is such a fundamental human need that a policy denying information is likely to significantly reduce the acceptability of elevator evacuations.

Elevator lobby monitors must be trained bow to quickly report information to and receive information from tbe control center. Verbal messages should be brief to avoid unnecessary delays and to maximize the efficiency of the control center. Emergency team members will need to quickly relay information needed by the control center on the numbers and types of persons and the conditions in the elevator lobbies. Monitors should have the information prepared before verbal communications begin, and should relinquish the channel as soon as they exchange brief status reports.

A protocol for transmitting and receiving status reports should be developed. (For a discussion of the content of communications sent to control rooms, see the chapter, COORDINATING AND DIRECTING THE EVACUATION. For examples of types of information that should be relayed to elevator lobbies, see the section INFORMATION NEEDS OF AND DECISION MAKING BY MONITORS AND OCCUPANTS in this chapter.) The protocol should govern whether these communications are initiated from the elevator lobbies or from the control room. Time permitting, the control room should honor special requests for more information. There should also be an understanding about how frequently control rooms can be expected to provide updates to elevator lobbies about waiting times for elevators and the status of the incident. Also, a public address or intercom system could be used to broadcast status reports to all elevator lobbies simultaneously, thereby reducing the amount of time that needs to be devoted to communications to individual elevator lobbies.

MANUALLY VS. AUTOMATICALLY DIRECTED EVACUATIONS

In the chapter covering the coordination of elevator evacuation, we compared and contrasted automatically and manually directed evacuations. In the example of a manually directly evacuation, coordinators manning the control center select an evacuation sequence for elevator lobbies and communicate the directions to operators who are running each elevator. In the example of an automatically directed evacuation, a computer routes the elevators and operators are not present. Call buttons in elevator lobbies notify the computer that people are waiting.

The need to keep elevator lobby occupants informed is just as great for an automatically directed evacuation. As indicated earlier, building occupants cannot be expected to passively wait for an elevator under ambiguous circumstances. This need is perhaps even greater where elevators are automatically directed to floors, because many people have a fundamental distrust of the reliability of "high technology." (Moreover, we expect that most people will feel reassured by knowing that coordinators are observing the operation directed by the computer, and will step in should that be required by the situation.)

There could be problems with not having elevator operators. The lack of elevator operators might be a significant obstacle to the acceptance of an automatic system. As with the computer that directs the elevators, building occupants' suspicions about high technology may cause them to hesitate to ride an elevator over which no human operator seems to have control (or the power to override the automatic system). Under nonemergency conditions, building occupants do have experience with elevators without operators, but elevator occupants still have some control over the calling and destinations of elevators under normal operations. During a fire incident, an automatically controlled system eliminates this control. We are uncertain about the psychological impact of missing operators. If research on actual installations reveals a problem, it may be possible to instill some perceived sense of control, either by providing an "operator" who could override the automatic control of the elevator, or by simply providing enough information to occupants so that they are convinced of the reliability of the automatic system.

VISITORS

In our study of staging areas, we found that the problem of directing visitors was not adequately addressed in emergency plans. Our analysis revealed that there were two different types of problems depending on the nature of the visit. Some visitors had an appointment to meet with one or more permanent building occupants. Other visitors were in the building without an appointment. They might be waiting to meet with a nonspecific official, or they might be visiting an exhibit, museum or performance. They might also be patrons in a restaurant or retail business.

Visitors who are meeting with specific permanent building occupants should not require special provisions. To the degree that permanent occupants understand and are willing to follow the plan, these visitors should follow suit. During one of the fire drills for staging areas, a visitor with a disability was told about the staging area by the building occupant that she was visiting, and was accompanied there by her host.

Visitors who are not meeting with particular permanent building occupants, or are in transit, do require special provisions. These visitors will need to receive instructions from receptionists, security guards, food service workers, tour guides, or other appropriate persons. The permanent building occupants in those jobs must be assigned duties as part of the building's emergency team. They should be trained to explain the life safety system in such a way as to instill credibility and trust. As indicated by the strategy, they might also need to ask tactfully whether any visitors are unable to descend stairs without risk or discomfort. As with permanent occupants, self-selection is probably the most accurate and sensitive approach to identifying persons who are best evacuated using elevators.

HUMAN FACTORS DESIGN CRITERIA FOR ELEVATOR LOBBIES

The study of staging areas demonstrated the importance of design considerations in getting building occupants to accept and use staging areas. We believe that this finding generalizes to elevator lobbies. The staging areas study also demonstrated that in the design phase, human factors can be neglected as the designers focus too narrowly on fire protection characteristics.

Size. An elevator lobby must be large enough to fit all anticipated occupants assigned to use the elevator if the lobby is on a fire floor. It should also provide sufficient space per person to grant some degree of psychological comfort: elevator lobbies should be large enough to avoid crowded conditions which would add to an already stressful situation. People waiting in the lobby will not willingly accept the same crowding that is common for a short elevator ride. Where a very small number of persons might be assigned to use the elevator and a small lobby will hold all of them, there is also a danger that the lobby will be sized so small that it induces a feeling of claustrophobia in some people. In our study, some staging areas were so small that they induced anxiety in a few persons who reported feeling "trapped." Non emergency considerations will probably assure a sufficiently large lobby if the elevator is used to transport a large number of workers to their offices at the beginning of the work day.

If a floor is sufficiently removed from a fire that the hallways will remain safe until the elevators arrive, the capacity of the lobby need not limit the number of occupants directed to use the elevators.

Lighting. Elevator lobbies need emergency lighting. Moreover, the level of illumination should not be so dim as to increase the level of anxiety.

Seating. In staging areas, a lack of seating was a common complaint. This problem applies equally to elevator lobbies. Persons with mobility impairments frequently have difficulty standing for long periods of time or sitting on the floor without risk of injury or considerable discomfort. Where strategies are used that might require lengthy waits, seating will be essential for occupants with physical disabilities or health problems. Where strategies call for all occupants to use elevators, and seating is not available for most of the occupants, the available seating should be reserved for persons with mobility impairments and other physical limitations.

Viewing panels facing inside the building. Consideration should be given to installing viewing panels that permit viewing of adjacent areas of the building, such as the corridor. This would provide information about smoke intrusion into viewable areas adjacent to lobbies. The information would be useful in the following ways:

- Lobby monitors could relay the infomation to the fire department and coordinators to provide them with a more accurate assessment of current conditions in the building.
- The degree of ambiguity would be reduced, thereby providing increased psychological comfort, especially when there is no smoke in the adjacent areas.

- Elevator lobby occupants would find the information useful when deciding whether to abandon the lobby and traverse adjacent areas to reach a stairway in another area of the floor.

- Elevator lobby occupants would find the information useful when deciding whether to abandon the lobby and use a stairway leading from the lobby because smoke in adjacent areas is threatening the lobby.

However, such a viewing panel could prove hazardous to elevator lobby occupants who have little confidence in the protection features of the lobby. Seeing smoke outside the lobby might encourage an occupant to "make a run for it." However, we believe that a good program for training and for keeping occupants informed during the incident would help minimize this possibility by providing occupants with a relatively accurate perception of risks.

Windows facing outside the building. In the staging areas study, a few persons expressed the desire for exterior windows in staging areas. They reasoned that they could be rescued through the windows in the event that fire fighters are unable to rescue them safely from within the building. The same logic would seem to apply to elevator lobbies in low rise buildings.

Communications. The human factors of communications equipment needs careful consideration. We observed instances of insufficient attention to the useability of communications equipment installed in staging areas, a problem that generalizes to elevator lobbies. The use of such equipment should be intuitively obvious as possible, i.e., user friendly. (See the chapter, COORDINATING AND DIRECTING THE EVACUATIONS, for more detail on communications devices.)

Signage. During the staging areas study, we found that signs were used in only a limited manner. While areas and features were often labelled, sign explaining procedures and the operation of equipment were largely omitted. Signs should not only label areas, features and equipment, but also explain their use.

Noise levels. High noise levels in staging areas were a common problem in our study of those installations. Auditory alarm signalling devices should not be installed inside of elevator lobbies because they prevent essential communications and add considerably to the stress felt by occupants. We expect that the barriers surrounding an elevator lobby will attenuate sounds from outside enough that the alarms will not interfere with communications, but will alert people waiting for elevators when the alarm first sounds. These assumptions should be confirmed during design and tested after installation.

MANNING ELEVATOR LOBBIES (THE EMERGENCY TEAM)

Job qualifications. It is common in many buildings to assign roles on the emergency team to persons of relatively little rank and authority. This practice is inadvisable (unless the individual is unusually well known and respected), because elevator monitors will be directing other building occupants. Elevator lobby monitors should be recruited consistent with the authority and respect that they are expected to command during an emergency. In addition to having their instructions respected, they must be credible informants in relaying information about the safety features of the building and the current status of an incident. Thus, building managers should ask clients to appoint people who are well respected, who have good verbal skills, and who have managerial or supervisory duties and demeanor. A well-designed training program should minimize the demands on these persons' time, thereby making their appointment more acceptable.

INSTALLING THE "FIRE EMERGENCY PLAN"

Once a system for using elevators to evacuate building occupants has been devised, it must still be installed. By installation, we mean all various aspects of ensuring that the system will function properly in the event of a serious fire. This chapter covers the following topics:

- Writing the plan
- Format of the written plan
- Content of the written plan
- Training methods
- Maintenance

WRITING THE PLAN

Reasons for writing a good plan. Writing a straightforward and easily understandable fire safety plan seems to elude many building managers. In our study of staging areas, we typically found lengthy plans that provided a jumble of poorly organized infomation. Another temptation is to simply copy a plan for use in another building without much regard to its applicability. These practices are unfortunate since a well written plan tailored to a specific building serves several important communication functions. Each of the following audiences can benefit greatly from a written plan.

- **System designers.** A preliminary fire plan should be an integral part of systems design. A written description of the life safety system for a building could be invaluable during the design phase. Some components that are tractable during the design stage become intractable once construction starts. Before finalizing the design of the building, including the design of the fire protection systems, it is important to perform an analysis to assure that all components of the fire safety system are properly considered. A preliminary fire emergency plan, which describes how the total system operates, should serve as basic input for this analysis.

- **Persons legally responsible for fire safety.** The written fire plan should describe how the total fire safety system operates to those who are responsible for fire safety. It should help assure the building owner, the building manager, and any interested government officials that the fire evacuation procedures are properly designed. If they find fault with the plan, changes can be made as appropriate.

- **Members of a building's emergency team.** It should serve as the fire safety manual for all occupants who have assigned tasks related a fire emergency. It should state the life safety strategies used and include the task description for each type of monitor or warden. It should describe the chain of command and contain the names and phone numbers of those having responsibilities during a fire emergency.

- **Building occupants at large.** It should contain a simple explanation of the fire plan and the use of elevators for occupants at large who have no special responsibility for others. It should contain sufficient information about the fire safety system to reassure the reader that the fire plan, including use of the elevators during a fire emergency, provides a high level of safety. In general, we would recommend a separate document for this function. Management should consider having a second special document for building occupants with mobility limitations.

- **Maintenance personnel.** The fire emergency plan should also address the need for special maintenance requirements to assure that the fire safety features of the building function properly in a fire emergency. Some of these features function only in fire emergencies or when specially tested. Problems would not become apparent during the normal functioning of the building. The importance of their duties will be more apparent by clearly stating the contribution that each hardware component has towards the overall system.

Who Writes the Plan. The Fire Safety Plan should be written by a team that includes individuals who have the following skills and knowledge: 1. a full understanding of the operation of the fire safety features including the characteristics of the elevator and elevator lobby that permit its use during a fire; 2. a full understanding of the general plan and the limitations of each of the fire safety strategies; 3. an ability to write clear English: and 4. an appreciation of the concerns of the occupants at large and the occupants with physical limitations. If outside experts are needed to assure that all of these skills are represented, they should be hired. A representative of the fire department may participate in the development of the plan; if not, the fire department should be given the opportunity to comment on the plan at all stages of its development.

The writers of the fire safety plan should have a reasonably accurate understanding of how building occupants are likely to behave during in a fire emergency and what actions they are likely to resist doing, even when it is part of the fire plan. The plan should not be written based on erroneous beliefs about occupant behavior, such as "People panic during emergencies" and "The less information given to people, the more likely they are to follow instructions." Because these myths about behavior are so prevalent, it will often be necessary to provide the writers of the plan with this information.

Efforts should be made to obtain input from the emergency team, occupants at large, and persons with disabilities. They will have insights that fire protection professionals, management and architects might not have. When we interviewed occupants in buildings with recently installed staging areas, in each building at least a few persons with disabilities complained to us about the perceived inadequacies of the provisions taken for their safety. But without an effort to solicit their input, less assertive individuals are likely to remain silent. This is a case where important activities from a technical standpoint are also good public relations.

Obviously, the occupants of the building cannot be involved in the design of the building before it is built. However, workshops can be conducted during the design stage with employees of prospective tenants or similar people.

FORMAT OF THE WRITTEN PLAN

Fire emergencies can be integrated into a plan for other types of building emergencies. Fire is not the only emergency for which the building management must prepare. There can be bomb scares, earthquakes, floods, tornados, etc. The fire emergency plan can be in its own document (or set of documents), but it is often better to incorporate it into a document covering other emergencies as well. One reason is that it is handier to keep all emergency plans together. Another reason is that the same basic procedures and emergency team roles serve for different types of emergencies.

There can be one document for all audiences or separate documents for different audiences. Certain audiences will often need additional information that will be of no value and little interest to other occupants. For example, secretaries may need special information about screening bomb threats, and elevator monitors may need more detailed information about the safeguards that allow elevators to operate during a fire emergency. It is important that each document be self contained. Occupants, monitors, and regulators should not need to review more than one document to learn all they need to know related to the fire plan.

One approach to obtaining the desired brevity is to have a separate document for each user group. Information can then be crafted for the audience. Another approach is to provide the information in modules. A base modules can contain the essential infomation described later in this section. Special modules can then be added for particular groups. The advantages and disadvantages of these approaches can best be discussed after several attempts are made in preparing the types of documents described in this section.

The written plan should be brief and carefully organized. Many written plans are lengthy only because they contain information that is extraneous. The emergency plan should not be a lengthy document. A well written plan will be brief and well organized. Brevity is a virtue but should not be an excuse for incompleteness.

Good organization is of paramount importance. Information that may be needed during an emergency must be found without delay. This material should be placed first in the document or clearly marked using tabs or other similar means. As a general test, someone who has never seen the document should be able to locate this type of information within seconds.

CONTENT OF THE WRITTEN PLAN

Regardless of how documents are assembled, all building occupants should receive documents containing relevant portions of the material described below.

- **Policy statements.** Policy statements should be included in distributed plans. Policy statements are desirable because they explain building management's commitment to safety, and because they may specify the responsibilities of the building occupants and tenants towards ensuring that the plan is followed and maintained. The statement should explain the legal obligations of building management, government agencies and employees, and other building tenants and occupants.

- **Life Safety Strategies.** It has been said that it is so difficult to make a system foolproof because fools are so ingenious. Building occupants must be provided with a clear course of action and the reasons for following it. Carefully stated life safety strategies will make the recommended actions crystal-clear to all building occupants. We strongly recommend that information be provided to building occupants so that they will be more likely to perform as expected and desired and not act "foolishly". The occupants should be informed of the general approach underlying the fire safety system. Specifically, they should become acquainted with the various life safety strategies being used and the related backup strategies. This information should be highlighted in the written plan. Occupants, who are familiar with and understand the general approach toward fire safety, should perform better.

  The plan should contain clear guidelines specifying which building occupants are targeted to use which life safety strategy. This is especially important if some occupants are expected to use the elevators and others are not.

- **Description of Fire Safety Features.** All occupants should have the opportunity to learn about the fire safety features of their place of employment. This is especially important when the building has features that are not commonly installed, such as fire safe elevators. Occupants will use these features effectively only if they are aware of the properties of the features and have trust in them working properly. The reason for including these features can be easily discussed by explaining how they contribute to the successful completion of the life safety strategies.

- **Responsible Officials and Their Assignments.** Everyone in the building should have access to the names, office phone numbers, and assignments of those particular employees who are responsible for their actions and safety during a fire emergency or a fire drill. Members of the emergency team need this information in case they need to contact those to whom they report, those who report to them, or those for whom they have particular responsibility. Occupants who have disabilities and who require assistance from a monitor should be able to determine who has the assignment to assist them. (This is not a substitute for the monitor contacting the person with a disability on a continuing basis.) This information must be frequently updated.

  This information needs to be readily available. It can be incorporated into the fire plan. The fire plan may be reprinted frequently with the updated information and distributed to all building occupants. (Some of this information could be in a building or corporate phone book as well.) Other approaches are to post the information in easily noticeable locations or to prepare and distribute inserts containing the names, phone numbers and assignments.

TRAINING METHODS

The material that should be covered in the training program for the general occupants (and the occupants with physical limitations) should include all the material in the fire plan.

Building occupants, and especially emergency team members, need to practice unconventional procedures. The distribution of a written fire emergency plan is insufficient by itself. Even a plan that is a well written self-instructional guide and reference manual will not reliably transfer the needed infomation. Training is especially important when the fire plan uses unfamiliar life safety strategies such as the use of elevators during fire emergencies. There are several reasons why written information is insufficient.

- Having people actually perform the required behaviors is a far more effective and efficient method for remembering performance skills.
- Building occupants may not study the materials to a degree that will ensure that procedures will be remembered.
- Building occupants may not understand the materials either because they are not well enough written or because the occupants proficiency in English is inadequate.
- Training provides some social interaction that stimulates interest and learning, and provides the opportunity for questions.
- Training provides performance feedback that helps persons responsible for emergency planning improve their training efforts.
- Training can alleviate fears and apprehensions, by giving each occupant a full explanation of how the elevator works and the features that have been installed to assure it functions properly.
- Training can and should provide occupants with an opportunity to express their concerns and fears; these concerns and fears can be addressed in the training session.

Fire drills should probably be the principle means for training occupants at large. The need for fire drills (often called fire exit drills) in large buildings has been well established for generations. The cost of a fire drill in an office building is very high in terms of employee time used and general work disruption. When everyone can quickly evacuate the building (e.g., a one story building with all exits at grade) the cost-benefit of a fire drill is problematic. (Section A-31-1.5.6 of the Life Safety Code points out that drills should familiarize occupants with emergency exits not habitually used.) The value of drills and the need for drills becomes greater as the building becomes taller and more persons work above street level, because the fire plan becomes more complicated. Section 31-9.1 of the 1991 Edition of the Life Safety Code recognizes this in its statement that: "In any building subject to occupancy by more than 500 persons or more than 100 persons above or below the street level, employees and supervisory personnel shall be instructed in fire exit drill procedures...and shall hold practice drills periodically where practicable."

The system can *not* be expected to work properly in a fire emergency without periodic fire exit drills. While drills are required in federal office buildings, they are not universally required in commercial office buildings, that is, they are deemed not to be "practical." The use of elevators, as an integral part of the fire emergency plan, may not be feasible without a program of periodic fire drills. Until the converse can be demonstrated, we recommend mandatory fire drills whenever the fire plan involves the use of elevators for evacuation of a portion of the general population.

Occupants of elevator lobbies must be taught to anticipate long waits. When elevators are used to evacuate occupants during a fire in an office building, occupants expected to use the elevators will be directed to wait in or near elevator lobbies, in somewhat crowded conditions, until the elevators amves. The wait, especially on floors that are not yet endangered, can be for a long time. Even if stairs are also used, it may possibly take up to one half hour or more in very tall buildings (although ten minutes appears to be a more common maximum). The wait will feel much longer than the clock time. There is a real question as to whether or not the occupants will wait patiently for that long a period of time. The probability of them waiting will increase if they are taught to expect the wait. While we do not suggest that occupants practice waiting in the elevator lobby during a drill for a half hour, or even half that time, waiting for elevators during a fire drill should increase the probability of occupants using the elevators as instructed during a fire emergency.

A program of fire drills must be sensitive to management-tenant relations. It is not unusual for building managers to conduct fire drills with very poor participation from tenants. A good program will accommodate tenants needs as far as possible without compromising the need to train a reasonably high (but unknown) percentage of building occupants. Too often, drills are based on the idea that only surprise drills are effective. But practicing procedures is the most important activity during the drills. Inevitable differences between drills and real fire evacuations will not necessarily interfere with that objective. The following measures can help establish such a workable program.

- The fire drill can be announced. Announced drills can both increase and decrease participation. An increase can be expected because occupants can fit it into their schedules. A decrease can be expected because occupants may stay away from their offices for the time when the drill has been scheduled.

- The fire emergency drill, if it is pre-announced, can be run for only part of a tall building. In a large building, this will decrease the time needed to conduct the drill, especially as regards waiting for elevators and stair access. It also should make the drill easier to evaluate. However, it will be important to notify the entire building that a drill has been scheduled to minimize confusion, and to alert occupants that some or all of the elevators will be unavailable for a period of time. If management-tenant relations permit, the precise time or floors of the building to be involved need not be identified in the announcement to maximize participation.

Fire Drill Performance and Feedback. Fire drills should not be regarded by building management as an administrative chore but, rather, as an opportunity for upgrading the fire safety of the building. After each drill, selected members of the fire emergency team should meet and review the results of the drill. For example, the time for evacuation can be compared with times in previous drills and the reasons for the faster or slower times can be discussed. Changes in strategies, procedures, written fire plans, or training programs can be initiated in these sessions.

These sessions should have a small enough group attending that it can be a true working session. It would be desirable in many cases for some of the attendees, such as floor monitors, to meet with some of their colleagues or subordinates in a preparatory meeting immediately following the drill so that the experiences of a wider group can impact on the meeting without have an unwieldy sized group at the meeting.

Those responsible for fire safety should set some performance goals for the drill. Times for evacuation is an obvious one. Timely reporting to the control center that a floor is cleared and universal cooperation are other possible goals. The post fire drill feedback meeting should review fire drill performance in terms of how well the goals were met. Corrective actions should be initiated where deemed appropriate.

Drills, as well as other training, should be conducted by the persons who have responsibilities during the actual incident. Those who wrote the plan should be teaching the emergency coordinators and the monitors. The monitors should help train the occupants at large. Training specialists may be involved in the training but all training sessions must involve people knowledgeable about the fire safety features to assure that the trainees have the confidence in the fire safety features that comes from interaction with the experts. Even if training experts are not involved in the conduct of the training, they should be involved in the development of the training program to assure that the training techniques are appropriate to the skills and interests of the trainees.

Training should not be restricted to a classroom type setting. It can include observation and demonstrations of the fire safety features. For example, it might include a visit to an elevator lobby where each occupant has an opportunity to talk to someone in the control room.

All employees who staff the control mom — and any member of management who might staff the control room during an emergency — should have extensive and continuing training. This training should include frequent hands-on practice for all coordinators who staff the control room. (See the chapter on COORDINATING AND DIRECTING THE EVACUATION for details about the tasks that coordinators will need to practice.) ***If we transfer the responsibility for occupants' choices of actions from the occupants to the fire emergency team and its supporting computers, each and every member of the fire emergency team should be fully trained. If they cannot be trained, they should not be assigned a responsible position.***

MAINTENANCE

Years ago, the basic fire strategy in office buildings was for all occupants to save themselves by evacuating using the stairs. This was based on the false assumption that large buildings could be quickly evacuated and that everyone could use the stairs or would be carried down the stairs and that the capacity of the stairways was sufficient. Now staged and partial evacuations are common and special procedures have been developed for building occupants who cannot use the stairs. Active fire protection systems have been mandated to provide for the temporary safety of some occupants while more endangered occupants are evacuated first. The safety of the occupants depends on the proper functioning of special equipment including communications systems, air pressurization systems, automatic closing of doors and dampers, and backup power supplies. The use of elevators to evacuate occupants during fire emergencies will necessitate the installation of still more fire protection systems.

Some of this **special** equipment is used only in case of fire or other emergency. While it is vital that this equipment operate properly, there often are **no** warnings when there are problems; they are not part of the normal operation of the building. Scheduled maintenance and tests are imperative. Clear maintenance instructions and test schedules must be made available to those who will do the **work** Local building management can decide **how** this can be best published and made part of the maintenance operation. It is part of the fire pian, even if published in a maintenance guide.

Training for maintenance personnel should emphasize that their work is vital to the successful operation of the entire life safety system. Evaluations of their job performance should reflect the importance of their duties to the life safety of the building occupants.

PROJECTS TO PROVIDE HUMAN FACTORS GUIDANCE FOR ELEVATOR EVACUATIONS

In this study, we have attempted to identify the human behavioral issues associated with evacuating occupants from office buildings using elevators. Our approach has been to use a system perspective to identify relevant human factors issues. However, we were limited by the lack of empirical evidence directly applicable to the problem.

Because there are no data from building evacuations using elevators, the findings of this report are necessarily speculative and general. They are based on the authors' combined experience and on one study of installations (staging areas) that are similar in some respects. Our conclusions are sometimes tentative. Our study raises as many questions as it answers. As with any design problem in its early phases, elevator evacuations requires careful research to avoid costly design errors.

The need for research extends to human factors. We have tried to demonstrate that elevator evacuations should be viewed from a systems approach that incorporates building occupants. Attempting to "remove" people from the systems designed to protect them is a common, but often costly mistake, in designing complex engineered systems. Moreover, we are skeptical that a totally automated system would be sufficiently reliable and that building occupants would trust it enough for them to comply with the emergency plan. We recognize the advantages of simplifying a design problem, but elevator evacuations are not simple, and human factors must be treated as an integral part of the research and development.

In this concluding chapter, we are suggesting a few projects that should provide key information needed to design an elevator evacuation system that is sophisticated from a human factors standpoint.

CONSTRUCTION OF SYSTEMS MODELS FOR ONE OR MORE SPECIFIC BUILDINGS

Background. The opportunity of building a model for one or more existing buildings will assist in refining the evacuation system and, to a limited degree, in its validation.

Methodology. A conceptual model for a working elevator evacuation would be constructed for one or more actual buildings. The following steps, consistent with the approach used in this study, could be employed.

1. Select one or more buildings with features that make it suitable for this analysis, including, but not limited to: (1) observable features that make the building appear to be usable for elevator evacuations (especially a layout conducive to elevator lobbies); and, (2) a building configuration (especially height) and/or occupant population that might make elevator evacuations desirable.
2. Select sets of strategies for analysis. (See the chapter in this report covering strategies.)

3. Design building features that would enable the selected strategy sets, perhaps including, but not limited to: elevator lobby partitions, elevators that will reliably operate during a fire, location for a control room.

4. Use mathematical models of fire and smoke spread to estimate at what times areas in the building would become uninhabitable. Use a variety of possible fire scenarios, assuming that the building features in step 3 have been installed.

5. Estimate the times that area would be cleared of building occupants using people movement studies of building evacuations, mathematical models of people movement using elevators, and assumptions about time periods to detect fires and for people to take action.

6. If building management and tenants are cooperative, conduct a people movement simulation using stairs and elevators to validate that portion of the model. If feasible, run the simulation for more than a single set of strategies.

7. Use the model to evaluate the relative risks of sets of strategies. Using a variety of fire scenarios, predict which sets of strategies provide the greatest safety margin for occupants, that is, which strategies are most effective at removing people from the path of fire and smoke spread. Use the model to identify problems and opportunities to assembling the systems components needed to implement the best strategy set.

HUMAN FACTORS REVIEW FOR CONTROL ROOM OPERATIONS

Background. Operations of the control room are vital to the reliability and efficiency of an elevator evacuation. Varying degrees of automation are possible, and perhaps necessary. Alternative approach to designing the tasks of persons coordinating the operations must be carefully studied to maximize efficiency and minimize errors. Once tasks are designed, persons with needed abilities can be recruited and trained appropriately. Interfaces between people and computer programs, communications devices, and informational displays should be analyzed and designed to minimize human errors.

Methodology. This study should begin with a literature review. Considerable human factors research has been conducted on related problems such as control room operations in power plants and cockpit crews in airplanes. This research should be reviewed for guidance.

In the likely event that the literature review provides insufficient guidance in itself, an empirical study using a control room mockup and simulation would provide valuable design information. The effects of task design on human performance needs to be examined empirically. The most cost-effective approach might be to build a simple control room mockup. Subjects could interact with a computer that provides data about conditions in the building. Elevator coordination tasks would be designed and subjects trained to perform them. This approach would collect valuable data on optimal task design, task allocation and team performance for coordinators working as a group, the evaluation of alternative communications devices, the development of decision aides for manually-controlled evacuations, and the design of communications and computer interfaces and the displays for tracking the status of evacuations.

INTERVIEW SURVEY OF EXPERIENCES IN HIGH RISE BUILDINGS

Background. Elevator evacuations in high rise buildings are complex operations dependent on a building management's ability to plan and train for the evacuation, and then to coordinate it once it is underway. All these activities unavoidably occur in a broader social context. This study is needed to find out whether the social context and human resources are ordinarily available to building management, and, if not, whether the resources can be developed and what obstacles might interfere.

Methodology. Interviews would be conducted with building managers, building tenants, building occupants at large (especially those with disabilities), and fire department and other regulatory officials. The following types of information would be collected

- What is the availability of qualified people to man control rooms?
- What is the quality of relations with fire departments and other regulatory authorities, especially as regards trust and cooperation, pre-fire planning, inspections, etc.?
- What is the quality of relations between building managers, tenants, and persons with disabilities, especially as regards fire drill practices, emergency planning, communications, cooperation, security, etc.?
- What are the beliefs and attitudes of persons with disabilities about their perceived safety and preferred treatment in high rise buildings?
- What are common maintenance practices and are they sufficient to ensure a high degree of reliability for hardware enabling elevator evacuations?
- If fire drills can be observed, useful data can be obtained about compliance with emergency plans, management approaches, estimates of preparatory times, behaviors of occupants at different levels of very tall buildings, etc.

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If elevators could be used in fire emergencies, the safety of building occupants with mobility limitations could be greatly enhanced and the time for all occupants to evacuate might be reduced. This report covers a study of human factors considerations related to the possible use of elevators for evacuations in fire emergencies. It covers the selection of the fundamental approach to organizing elevator evacuations for specific buildings; the coordination and direction of the evacuation; the decision-making, Information and communication needs to permit a coordinated evacuation; and the documentation, manning and training requirements to permit a proper implementation of the fire emergency plan.

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