Perspectives of Occupants with Mobility Impairments on Evacuation Methods for Use during Fire Emergencies

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ABSTRACT

Since the tragic loss of life in the World Trade Center disaster, efforts have refocused on the provision of safe and efficient evacuation procedures, especially for occupants who cannot negotiate exit stairs without assistance. Several evacuation options have been designed specifically for people with mobility impairments, including occupant evacuation elevators (OEEs). Face-to-face interviews were conducted with 51 participants with mobility impairments working in buildings located in five major metropolitan areas within the U.S. The dual goals in this study were to gain an understanding of how building occupants with mobility impairments evacuate multi-story buildings during fire emergencies and to identify perspectives on the use of elevators during fire evacuations. Data analysis of interviews highlighted the benefits and concerns of study participants involving both typical building evacuation methods (i.e., emergency stair travel devices and areas of refuge), as well as evacuation methods using elevators. This study also highlights improvements that can be made to elevator systems, particularly OEEs, to reduce anxiety about fire evacuation and increase trust in the occupant evacuation elevator system via a variety of means, including education and consultation in preparation for the evacuation, information and attention to occupant needs while the evacuation is taking place, and two-way feedback and discussions afterwards. Key to all of these improvements is the need to include those with mobility impairments in the planning and execution of fire evacuations and to facilitate their ability for self-evacuation as much as is practicable. The results of this study led to guidance on evacuation planning and procedures, the use of existing elevators for evacuation of people with mobility impairments, and the use of occupant evacuation elevators.

KEYWORDS: egress; elevators; people with mobility impairments; evacuation methods

INTRODUCTION

> "With the time it takes to get me out of the wheelchair into the stair chair [and] get me down the steps – just the process involved and then the time, and then the danger of doing that to me and the people that are trying to help me – going down the elevator is a way, way better way to do it if it can be done." (Participant CA)

One of the nation's largest evacuations occurred at the World Trade Center (WTC) in New York City on September 11, 2001. More than 2 000 building occupants perished in the disaster. An investigation of the events preceding the collapse of the building was carried out by the National Institute of Standards and Technology (NIST) [1], resulting in a list of recommendations to improve the safety of high-rise buildings, their occupants, and emergency responders. The Final Report recommended that tall buildings be designed for timely full-building evacuations during building-specific and large-scale catastrophic events [2].

Since the tragic loss of life in the WTC disaster, engineering efforts have refocused on efficient evacuation procedures, especially for occupants who cannot negotiate exit stairs without assistance. Several strategies/methods have been designed to address the evacuation needs of people with mobility impairments, including emergency stair travel devices, areas of refuge, and occupant evacuation elevators (OEEs) [3]. Emergency stair travel devices permit assistants to transport someone down (or up) the stairs,

either by guiding the device (if in contact with the stairs) or by carrying it. They are sometimes referred to as evacuation chairs or stair chairs. An area of refuge is a location within the building where a person can safely wait for evacuation assistance. OEEs are elevator systems designed to enable safe occupant evacuation during fires [4].

Both emergency stair travel devices and areas of refuge pose some potential problems from the evacuee's perspective. Transferring into the emergency stair travel devices means giving up the independence granted by the person's mobility aid[1] and relying on the help of others during the evacuation process – possibly longer if the mobility aid is left behind. And in at least one incident, emergency stair travel devices were found to have slowed down evacuation speeds of others using the same set of stairs [2]. Researchers have studied attitudes toward areas of refuge and found that many respondents were uncomfortable with the idea of remaining in them for more than 10 minutes without assistance. They expressed concerns about being forgotten, not knowing how long they would have to wait, and being isolated [5].

A more promising means to improve evacuation capability of people with mobility impairments, at least in new construction, is the OEE. Simulation studies with a mix of occupants have shown that the use of elevators improves evacuation times and allows people with mobility impairments to evacuate at the same time as other occupants [6]. OEEs allow people with mobility impairments to self-evacuate, with their mobility aids and without depending on the assistance of others.

In recent years, several efforts have been established to improve occupant safety during fire evacuation of tall buildings. The International Code Council (ICC), the National Fire Protection Association (NFPA), and the American Society of Mechanical Engineers (ASME) have developed requirements for the use of elevators for both occupant evacuation and fire fighter access into buildings [7,8,9]. To support the development of these standards, research on elevators by NIST and others has primarily focused on the technical aspects of ensuring safe and reliable evacuation for the occupants of tall buildings.

While many of the technical challenges regarding the safe use of elevators during evacuations have been overcome, others are still being addressed [3]. Limited data or understanding is available on how occupants, particularly those with mobility impairments, can most effectively evacuate buildings during fire emergencies. The main purpose of this study was to address the need for research on the ways in which elevator technologies could be appropriate and should be considered for fire evacuation. This is particularly pressing for the population that may benefit the most from this option.

This paper focuses on the perspectives of people with mobility impairments on methods for evacuation during fire emergencies from multi-story buildings in the United States. The paper first presents the perspectives of people with mobility impairments on typical evacuation methods, as well as methods using elevators. This paper then identifies improvements that can be made to the new OEE systems, based on these perspectives, to improve comfort levels of people who might use them during fires. The results of this study led directly to guidance to assist architects, engineers, and facility managers to further improve evacuation strategies/methods and the experience for those with mobility impairments, including the use of elevators designed for safe evacuation.

METHODOLOGY

A brief discussion of the study's methods will be presented here, since other publications have provided extensive detail on the study's data collection efforts, interview questions, and qualitative analysis techniques [10,11].

A qualitative approach was chosen to carry out this research project. The goal of qualitative research is to uncover the range of behavior of a group of people related to some topic or issue and to understand the motivations that drive the behavior [12]. This is accomplished through in-depth study of a group of people

[1] A mobility aid is a device designed to assist an individual in moving from one location to another. Examples of mobility aids include manual and power wheelchairs and scooters, walkers, crutches, and canes.

using methods such as interviews, direct observation, and analysis of archival data [13]. The results of qualitative research are descriptive rather than quantitative.

In this study, since it was important to understand previous evacuee behavior and their reflections upon this behavior, face-to-face, in-depth interviews were conducted with 51 participants with mobility impairments working in buildings located in five major metropolitan areas within the U.S. Disability advocates from each metropolitan area were identified through a chain of referrals and asked if they would be willing to help with recruitment. NIST researchers worked with the disability advocates to identify potential participants. NIST researchers then contacted each potential participant via email or phone to describe the purpose and goals of the study and request his or her participation. Interested individuals were scheduled for a face-to-face interview. The format of the interviews was semi-structured, with a set of brief background questions followed by open-ended questions that allowed the flexibility to follow the participants' leads during the interviews.

During the interviews, participants were asked about their experiences with building evacuations and evacuation training, their comfort level and concerns regarding the evacuation options with which they were familiar, and their thoughts about the use of elevators for evacuation during fire emergencies (both existing elevators and OEEs). The semi-structured interview protocol consisted of a list of basic questions to be covered by the interviewer plus optional probing questions to draw out more detailed information and encourage the recounting of anecdotes. The questions included demographics, background information on the workplace and on mobility issues, and in-depth questions on everyday activities, fire evacuation experience, fire evacuation procedures and training, and fire evacuation by elevator. Near the end of each interview, participants were shown a short video describing technical and operational improvements incorporated into OEEs that could allow this type of elevator to be used for evacuation during fires. After the video, participants were asked for their comments.

Once interviews were completed and transcribed, qualitative analysis techniques were used to organize the information from the interviews and develop insights. An organized list of themes, i.e., a coding structure, was developed based on the data. All coding and analysis for this study were carried out using NVivo[2] (a software platform that provides tools to collect, organize, and analyze qualitative source materials).

The procedure for developing the coding structure began with importing all interview transcriptions and notes into NVivo. After the researchers on the project team finished reading the full set of transcriptions, an initial *a priori* code list based on the research questions was constructed. The team discussed and refined the codes in multiple meetings. During these meetings, each code was operationalized, such that its definition distinguished it from other concepts and allowed interview text to be assigned under it with as little ambiguity as possible. Issues regarding the usage of each code were identified and resolved, and the entire code set was assessed for its effectiveness in categorizing the full range of data of interest. Examples were developed for each code to help maintain coding consistency across researchers. The final set of codes (and subcodes), along with their operationalized definitions and examples, can be found in Butler et al. [10].

Once agreement had been reached on the code list, two researchers individually coded the entire set of 51 interviews. Each coder went through the transcript or notes for each interview carefully, assigning the text to codes as relevant. Some text was assigned to multiple codes, and some text was not assigned to any specific code. Some codes, particularly those that related directly to basic questions, received text from every interview, but other codes were addressed by only a subset of participants.

Comparison of the coding results from the two researchers revealed that there was considerable overlap in the assignment of text to codes, indicating that the coding process was reliable and consistent. Interrater

[2] Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the entities, materials, or equipment are necessarily the best available for the purpose.

reliability was not further quantified. In cases where discrepancies in coding existed (i.e., some text was coded only by one researcher), the additional coding was accepted and reconciled during the analysis phase.

For analysis of the data collected in this study, the analysis method framework, whereby data are classified into themes, concepts, and categories, was used [14]. First, the textual data under each previously-developed code was further analyzed, using systematic exploration of the issues that were common across many participants, as well as issues that were important to only a few or only under certain circumstances. Then, new subcodes were added to further separate the material into appropriate categories, thus reducing the complexity of a large amount of text to a manageable level.

To assist with the analysis, data was organized into a spreadsheet by participant. Summaries were developed for various categories that are deemed relevant in building evacuation, including demographic and disability information; evacuation experiences, plans, and training; and attitudes toward various evacuation options. The spreadsheet facilitated the determination of themes that were common across many participants, as well as those that were more dependent on individual situations. These themes provided the foundation around which the study's report was written [10], including occupants' inputs on the benefits and concerns of existing evacuation methods, their perspectives on emergency evacuation planning and training (including steps that they have taken to develop their own plans), and their thoughts on the benefits and concerns surrounding new OEEs. This article focuses on occupants' inputs on emergency stair travel devices, areas of refuge, and elevators. The larger report [10] provides perspectives on a broader range of evacuation methods (e.g., being carried, taking stairs using a wheelchair, and walking/sliding/crawling down stairs) as well as evacuation planning and training.

The following section briefly describes the sample of people who participated in this study, including information on demographics, geographic location, disability status, and other important participant characteristics. Additional information on the study's participants can be found in Butler et al. [10].

STUDY PARTICIPANTS

Fifty-one participants with mobility impairments working in buildings located in five major metropolitan areas within the U.S. took part in the study. Of those, 27 were male and 24 were female, with ages ranging from mid-20s to over 60 years (10 participants were between [26 and 35] years old, 14 were between [36 and 45] years old, 11 between [46 and 55] years old, and 16 were over 56 years old).

The study protocol did not include questions about the nature of the disability, but many participants volunteered information about the cause of their mobility difficulties. The range was broad and included congenital conditions, progressive diseases, and injuries.

The participants used a variety of mobility aids at work. As seen in Table 1, the vast majority (42 participants) used wheelchairs at work, evenly divided between power and manual wheelchairs.[3] Interviews were also conducted with people using crutches, canes, walkers, scooters, and a portable oxygen supply. One participant had a service dog that fetched items, steadied the owner, helped with transfers onto chairs and beds, and drew attention when help was needed. The sum of the number of mobility aids in Table 1 is greater than 51 because several participants used more than one aid while at work.

Table 1: Mobility aids used by participants at work

Wheelchair (Power / Manual)	Crutches	Cane	Rollator / Walker	Scooter	Other
42 (21 / 21)	5	4	3	2	4

[3] Participant characteristics reported here are accurate and agree with those presented in the final report on this study [10]. Numbers may differ slightly from those presented in a preliminary symposium paper, since at the time that this work was presented in 2015, data analysis was still ongoing [11].

Workplaces and Locations within the Workplaces

Participants in this study worked in buildings that were owned and managed by various organizations. These included city, state, and federal government buildings, school facilities, commercial office buildings, health care facilities, and non-profit centers. Some buildings were iconic and others were nondescript, with heights ranging from two stories to well over sixty stories in height.

Each participant identified the floor on which he or she spent most of their time while in the building. Usually this was where his/her office was located. It should be noted, however, that many participants described an active workday during which they traveled up and down throughout the building for meetings, discussions, and work breaks. This means that an emergency could occur at a time when they could be located on a floor other than where their office was located.

Table 2 shows the floors on which participants were primarily assigned to be located during their daily work activities. As noted, these locations are widely distributed vertically throughout a multi-story building. Participant discussions made it clear that for many, in the absence of an elevator, traversing a single flight of stairs either in an upward or downward direction provided as much of a barrier to independent movement as traversing a dozen flights of stairs. Almost all of the participants, i.e., anyone not located on the ground floor (see Table 2), depend on elevators to travel vertically within their workplaces on a daily basis.

Table 2: Floors on which participants work

Floor								
Basement	**Ground**	**2**	**3**	**4-5**	**6-8**	**9-13**	**14-35**	**N/A***
3	5	6	8	9	7	5	6	2

*It was not possible to identify one primary building, and therefore, a primary floor number, for a couple of participants; these are the two labeled as N/A, for not applicable, in the data.

The following sections provide results from interviews with the 51 participants of this study. The first section of this paper presents their experiences with and perspectives on typical building evacuation methods, namely emergency stair travel devices and areas of refuge. The second section presents their experience with and perspectives on the use of elevators for evacuation. This discussion will highlight participants' perspectives on the use of existing passenger elevators, existing freight or service elevators, and occupant evacuation elevators, to begin to develop new procedures for the use of elevators during fires that meet the needs, requirements, and concerns of people with mobility impairments.

EXPERIENCE WITH TYPICAL BUILDING EVACUATION METHODS

During the interviews, study participants were asked about their experiences with building evacuations during a fire or other emergency incident. Half of the study participants reported that they had experienced a building evacuation during an emergency incident at some point during their lives. An additional eight people had been in emergency situations but had not evacuated – either they had sheltered in place or the all-clear was sounded before they had a chance to evacuate. Almost all participants without these direct experiences were able to describe their participation in an emergency egress and/or relocation drill (e.g., fire drill), during which they at least talked through the procedures to be followed.

The participants in this study mentioned a number of methods by which people with mobility impairments could use to evacuate a building during a fire emergency. Some were methods that they had trained on or used during a fire drill or emergency; others were methods that they had heard of or had thought of using. These included emergency stair travel devices, areas of refuge, walking or crawling down the exit stairs, being carried by coworkers or fire evacuation personnel, and the building's existing elevators (either passenger or freight/service elevators). Use of the stairs with minimal assistance from others included walking with or without crutches; crawling using hands, feet, or buttocks; and controlled descent using the

wheelchair. During the study, participants described their thoughts about and experiences with all of these methods, including potential risks to their own safety and the safety of those assisting them [10].

This paper discusses only a few of these methods, focusing on those that are most typically used in fire evacuation planning. This section presents perspectives of study participants (both benefits and concerns) on the methods that typically exist as part of current emergency evacuation procedures for buildings, i.e., emergency stair travel devices and areas of refuge.

Emergency Stair Travel Devices

Code-compliant exit stairs are well-protected during fire emergencies [4,15]**.** Emergency stair travel devices provide an option for getting people who cannot navigate stairs on foot out of the building during an emergency [16,17]. Once individuals transfer to the device by themselves or with assistance, they are strapped into the device to prevent slippage and falls. Emergency stair travel devices provide an evacuation option for some users. Some models are motorized, giving them the ability to move both up and down the stairs. More inexpensive versions require assistants to lift and carry the evacuation device and individual.

Emergency stair travel devices allow people with even severe mobility impairments to exit the building via the stairs.

> "If everybody was evacuating I personally would prefer that there be somebody who takes the responsibility to get me down with an evacuation chair rather than waiting for the fire people to come. That's just how I feel and I feel really strongly about it. I've heard horror stories." (Participant CF)

Several study participants expressed a desire not to be the last person out of the building. If they are using an emergency stair travel device, they could begin preparation procedures involved in the use of this device. Once the individual is transferred into the device and secured in place, they may enter the stairwell along with their assistants.

However, study participants did express concerns associated with the use of these devices. The primary concern raised by study participants, particularly those in power wheelchairs, was leaving their mobility device behind. While manual wheelchairs and crutches may be carried down the stairs by coworkers, power wheelchairs are very heavy--300 pounds or more according to study participants. If power wheelchair users transfer to an emergency stair travel device, they will be able to exit the building but they will have to abandon their mobility devices. For them, loss of their mobility aid is a major concern – one that for some impairs their ability to continue with daily life. Participant AN expresses concern over the prospect of leaving equipment behind:

> "It's always an issue...letting go of my equipment, because so much of my health, my mobility, and my independence is tied to a very customized piece of equipment. It's not like, 'Oh okay, I'll go pick up an extra one at the grocery store.'…It's more than just we are being stubborn and we don't want to leave our chairs behind. It's a survival issue, quality of life, survival." (Participant AN)

Other concerns included physical risk, anxiety, and the need for assistance and training. Many study participants expressed their anxiety about using an emergency stair travel device. Because of the need to transfer from the mobility device into the emergency stair travel device, there is some physical risk for both the individual being evacuated and the people assisting him or her. Some participants were able to transfer themselves; however, for those who cannot self-transfer, the possibility of being dropped during transfer is a concern. Injuries may also result from conditions such as brittle bones and fragile skin, or from body support that is provided by their mobility device but not the emergency stair travel device. Participants were also concerned that their coworkers could be injured while assisting with the device.

An additional concern is the fact that an emergency stair travel device can carry only one person per trip. If there are more people waiting to be evacuated than there are devices, the device must be returned to the

floor in order to help the next person. This is a slow process for motorized devices that can travel up as well as down; devices that are gravity-driven must be brought back up by the stairs or by elevator.

Areas of Refuge

Evacuating all occupants from a high-rise building could require a considerable amount of time. One proposed solution for providing safety for people with mobility impairments is an area of refuge. Areas of refuge allow individuals the opportunity to remain in (or with) their mobility devices in a protected area while they await either resolution of the emergency situation (such as determination of an erroneous fire alarm) or evacuation assistance from emergency responders.

Some participants appreciated the ability to find protection if they are unable to readily evacuate in a fire situation; even seeing these locations as places for temporary protection until the initial rush subsides. Design features for these areas may include sprinkler systems, fire and smoke resistant walls, ceilings and doors, and two-way communication systems [4,18,19]; however, this is not always the case in every building [10]. Study participants' perceptions of areas of refuge ranged from corridors to fire-rated exit stairs to office lunch rooms, where they have been instructed to wait in an emergency.

Even with protections in place, many participants described significant anxiety about using the area of refuge. According to participants, they know that their ambulatory coworkers are able to exit the building and get to a safe place, while they are left behind. This is a situation that results in anxiety for many. Without regular communication and credible assurances that help is on the way, people are left to wonder when first responders may come, if at all, to assist them with evacuating the building.

In addition, some areas had problems with accessibility. Participant BB further explains these concerns:

> "I'm supposed to go out into the hallway, open up a door to the stairwell, which I cannot open myself. And it's a heavy door because it's fireproof. And I'm supposed to wait up in the stairwell – there's a designated spot up there – and I'm supposed to grab the phone that's in there, which I can't reach, and someone in security is supposed to pick up and I'm supposed to let them know that I'm up here." (Participant BB)

For some, the anxiety associated with the area of refuge is severe enough that they refuse to consider it as a viable option. Participant AV went so far as to say: "I'm not staying in the building; I'm using every resource I have to get the hell out of the building."

THE USE OF EXISTING ELEVATORS FOR EVACUATION

Although not generally the norm in current emergency plans for building evacuation during fires in the U.S., existing elevators may be available for use. ASME A17.1 Safety Code for Elevators and Escalators defines elevator operation in existing buildings during a fire emergency [9]. In Phase I, activation of smoke detectors or other automatic fire detectors in a lobby or machine room associated with an elevator automatically recalls the elevator to a designated level. In Phase II, elevators are under the control of firefighters. Firefighters, for example, may use elevators to evacuate building occupants with mobility impairments.

Before participants were presented with the video on OEEs (i.e., those elevators that are safe to use in fire emergencies), some clarified their perspectives and even experience with existing elevators – both passenger and freight or service elevators – for use during fire emergencies.

All of the buildings in this study had elevators that participants used to travel vertically during the course of their work day. These are otherwise known as existing passenger elevators. Buildings also contained freight or service elevators. Freight elevators, whose primary purpose is to carry freight and which are reserved for the exclusive use of the operator and freight handlers, are not required to meet ADA or ABAAS guidelines

[18]. Service elevators may simply be a larger passenger elevator placed with other passenger elevators or may be in a separate location. They would typically meet appropriate guidelines.

Although it was well known among the participants that elevators should not be used during fire evacuations, some study participants had tried the elevators during a fire drill or emergency incident, found them operational, and taken them.

Additionally, participants described many benefits that would be gained if this option were available to them. These include familiarity and ease of use (especially in the case of existing passenger elevators), the ability to move many people quickly, and the safety and independence of remaining in their own mobility devices. In the case of one non-profit agency in which many employees and most of their clientele are disabled, a study participant described a procedure for using elevators for evacuation in the time period before first responders arrive at the scene:

> "We have this other program that I prefer, and I've used, is that you get to the elevator, you push the help button,[4] someone on the first floor, and they will manually work the elevators to get as many people who cannot use the stairs down before the fire people come." (Participant AG)

Using an elevator during evacuation enables people with mobility impairments to keep their mobility device, and their independence, throughout the procedure. Many of the participants depend on their mobility device to maintain their health, mobility, and independence. Wheelchairs may be highly customized to provide support where musculature is weak and to prevent pressure sores. One participant with a neuromuscular disability explained that the tilting capabilities of the wheelchair allowed him/her to lean back to take a deep breath and to adjust his/her position to help with pain and balance. Some participants described the risk of injury from being picked up in order to transfer to an evacuation device or to be carried. The risk of injury to assistants is also avoided when the elevator is used.

Additional benefits were identified for the freight or service elevators. First, some participants perceived them as safer than the passenger elevator, because, often times, their location in "out-of-the-way" or because they may be better maintained. Also, they are often larger than passenger elevators, which are intended to transport people only. In some buildings, the freight elevator is capable of traveling to every floor in a building, whereas certain passenger elevators may only travel to a designated number of floors in a building.

However, participants identified concerns with the use of existing passenger and freight or service elevators during fire emergencies. The knowledge that they were not supposed to use the elevators in case of a fire was enough to discourage some. Others worried about specific safety issues associated with elevators designed before the development of OEEs, including the need to communicate with personnel outside the elevator if something went wrong. Experiences with waiting for the elevator to arrive, trying to enter a crowded elevator in a large wheelchair, and stopping at multiple floors on the way down detracted from the image of the elevator as a rapid means of evacuation.

Related to their potential popularity, study participants considered priority use to be a key procedural concern. People who do not have mobility impairments may readily use the stairs. Those for whom the stairs are a slow, difficult, and perhaps impossible choice would hope and expect that they would be given top priority in using the elevators to leave the building. Other procedural concerns included whether space would be available for a wheelchair in a small or crowded elevator, whether elevators would open at every floor even if they were full, and the order in which the evacuation would proceed. Participant AP described the concern with priority in the following way:

> "I'd say my number one practical concern is that when I think of elevator usage during an emergency, I'm like, 'Oh awesome it'll be worse than waiting for an elevator in rush hour or any other time when elevators are in demand.' …I just have

[4] This is a special designation associated with this building; not necessarily a feature in every building.

> a feeling that it's going to be hard to enforce [rules that limit those who use elevators in an emergency]. Like, 'Only the people who really need this are going to be in and that'll be half the building.'" (Participant AP)

Additional concerns identified for freight or service elevators had to do with the function of the freight elevator as servicing the building in a different way than the passenger elevator, and with issues of accessibility for people with mobility impairments, who are not the usual or intended users. Because a freight elevator is normally used for a specific purpose, use of these elevators may be controlled through special keys or keycards. In these cases, either an escort or possession of the key would be needed to gain access.

As far as accessibility concerns, the design of an enclosed lobby for the freight elevator may make entry difficult for those with mobility impairments. Entrance doors to the lobby may be too heavy for one to open effortlessly. In addition, the enclosed lobby and means of egress leading from the enclosed elevator lobby may be cluttered with supplies or equipment, reducing the means of egress width necessary for access or egress by a wheelchair. Lastly, the freight elevator may discharge onto a loading dock rather than to an accessible exit from the building.

THE USE OF OEEs FOR EVACUATION

This study, and more specifically, participants' perspectives about typical evacuation methods and existing elevators, demonstrated a need for better evacuation options for building occupants with mobility impairments. Improvements in design, procedures, and education can make it possible to evacuate people from tall buildings using elevators [20]. A history of this effort includes a 1993 NIST workshop on elevator use during fires [21,22].

The video on OEEs presented several features that address the safety and anxiety issues associated with waiting for and using existing elevators for fire evacuation, including protection against heat, smoke, and water; communication; and direct transport to the main exit discharge floor. In addition, people with mobility impairments can evacuate at the same time as everybody else, using the same elevator they use to enter and exit the building during their normal workday (which is now an OEE) while remaining in their mobility device.

After being shown a video on OEEs, participants were asked their opinions about using an OEE for evacuation, including benefits, concerns, and recommendations for improving the design. In particular, they were asked to contrast the OEEs against the elevators they use every day, to find out whether and by how much the information presented in the video had resolved their concerns. This section presents the perspectives of the study participants on these questions.

Benefits of OEEs

Many benefits were discussed by the study's participants on the use of OEEs during fire evacuations, including safety; feelings of comfort or relief, including independence; communication; speed and efficiency; and the universal nature of the evacuation method.

Above all, the study participants appreciated the intent of OEEs to provide a safe way of evacuating the building via elevator. The design of OEEs addresses the risks from electrical failure and smoke and water penetration in traditional elevators. For those with sensitive skin tissue or fragile bones, OEEs also appear to be a safer option than transferring into and being transported in emergency stair travel devices.

The psychological benefits of the OEE appear to be numerous. People with mobility impairments do not have to wait in an area of refuge wondering if anyone is going to come to evacuate them. Instead, they saw the OEE as a way of getting out of the building quickly, alongside their coworkers and without waiting for assistance. They can leave with their mobility device without having to worry about what they are going to do when they get to the street level. They also do not have to be concerned about who is going to assist them or if anyone will be in the office at that time to assist them. They can maintain their independence

throughout the evacuation. Most participants stated that the OEE as presented in the video made them feel more secure, relieving their anxiety about fire evacuations.

Study participants were also enthusiastic about two-way communication with emergency personnel that would be present both in the elevator lobby and in the elevator itself. They found it reassuring to have a message board displaying information about the status of the elevator, including the fact that other floors were being evacuated. This feature would allow both their coworkers and them to make informed decisions on whether to wait for the elevator, take the stairs, or travel to an area of refuge.

Running the elevator in an emergency mode that brings the elevator straight from the floor being evacuated to the ground floor was also appealing. Participants appreciated both that this system prioritized the people on the floors with the greatest danger and that the trip would be much faster without stopping on intermediate floors (especially if the elevator is already full). Participants also appreciated that the OEEs could carry large numbers of people quickly out of the building.

Finally, a small number of participants expressed their enthusiasm about the elevator as a universal option that everyone could use to evacuate the building in case of emergency. These people saw the OEE as an inclusive method that erases the differences between those with and without mobility impairments, enforcing the view of each other simply as coworkers.

Concerns with OEEs

Although the concept of OEEs was generally well-received, participants still voiced concerns about their use. These concerns could generally be classified as continuing anxiety about physical danger, policy issues such as priority evacuation for those with mobility impairments, and aspects of elevator design that were not addressed in the video.

For OEEs to be successful, occupants need to consider them as a safe option. A major educational effort would be required to counter decades of the message that elevators must never be used for evacuation in a fire. Some participants would be satisfied with a simple declaration that the elevator in their building is now safe to use in a fire emergency. For others, reassurances that OEE design had taken care of problems with electricity, heat, smoke, and water would not be convincing enough. These participants wanted additional proof of these claims before they could let go of concerns that the elevator could fill up with smoke, the elevator could stop working, or they could be trapped. They will need to be convinced with technical explanations of how the system works, test data and other evidence. Ideally, a knowledgeable expert would provide this information in a setting that allows the occupants to ask questions.

Similar to concerns with passenger and freight or service elevators, many of the study participants expressed concern over priority use for OEEs. Since using the elevator would be the quickest way out of the building, especially on high floors, people with mobility impairments may be competing for space with those who are capable of evacuating using the stairs. Participant AP expressed concern about OEE priority in the following way:

> “I think [the OEE video] doesn't address the crowding issue at all. In fact, I think my vision of having the elevator doors open, it'd be like a packed car already. And it wouldn’t just be five people waiting for the elevator, it'd be like the whole floor or whatever. So I just don't think there's a way to manage that because I think most people are going to perceive that to be the fastest, easiest way to get out. So whether they need to do it that way or not, they will do it that way.” (Participant AP)

Of particular concern to users of large wheelchairs is the amount of space they require, which makes it difficult to squeeze in after the elevator starts to fill. Additionally, some participants were concerned about whether others in the building would give them priority without some kind of enforcement.

Participants mentioned that some occupants in their building may have hidden disabilities that they have not shared with coworkers or human resource staff, but that would make it difficult to walk all the way down from a high floor. These could include heart or respiratory conditions, fatigue, illness, or temporary

injuries. This makes setting the priorities for OEE use during emergencies a task that requires careful thought.

Another concern was how the decision would be made as to which floor would be evacuated first and in what order the floors would proceed. This concern highlights the need to educate building occupants on the codes and standards developed for OEEs, which include the order of evacuation based on the floor or floors that are compromised by fire and/or smoke.

POTENTIAL IMPROVEMENTS TO EMERGENCY PROCEDURES INVOLVING ELEVATORS

Overall, a significant amount of data was collected and analyzed for this study on evacuation experiences and perspectives of people with mobility impairments on current (typical) and new evacuation methods for buildings during fire emergencies. These methods included areas of refuge and emergency stair travel devices (both of which are typically used in U.S. building emergency evacuation plans), as well as existing passenger and freight or service elevators and OEEs[5]. A summary of the benefits and concerns of the study's participants related to each type of evacuation method are provided in Table 3.

Table 3: Summary of benefits and concerns of evacuation methods

Evacuation Method	Benefits	Concerns
Emergency stair travel devices	• Ability to evacuate the building, along with coworkers	• Loss of mobility device • Physical risk • Anxiety • Requires assistance from others • One emergency stair travel device per person per trip
Areas of refuge	• Safety in a known location, with mobility device, while waiting for rescue	• Fear and anxiety of being left behind (not evacuating the building) • May be inaccessible and unusable
Existing passenger elevators	• Familiarity and ease of use • Means to evacuate the building quickly and easily • Ability to keep mobility device • Safety of others (who assist participants)	• Fear and anxiety • Lack of communication • Wait time • Crowding • Stopping on multiple floors during evacuation • Lack of priority use
Existing freight or service elevators	• Higher perceived safety levels (for participant and for assistants) • Means to evacuate the building quickly and easily • Ability to keep mobility device • Larger elevator car size • Accessibility of elevator cars to every floor in building	• Fear and anxiety • Lack of communication • Wait time • Crowding • Stopping on multiple floors during evacuation • Lack of priority use • Inaccessibility to occupants, especially people with mobility impairments
Occupant evacuation elevators (OEEs)	• Familiarity and ease of use • Higher perceived safety levels • Feelings of comfort or relief,	• Continued anxiety about physical danger (need evidence of safety and proper design)

[5] It should be noted that other methods for evacuation, including being carried, crawling or sliding on the stairs, taking the stairs in a wheelchair, and walking down the stairs (with assistance) are discussed in Butler et al. 2016 [10].

	including independence • Access to communication • Means to evacuate the building quickly and easily • Universal nature of the evacuation method	• Lack of priority use

Based on these perspectives, study participants were then asked what improvements could be made to training, education, emergency procedures and/or design to ensure the safe and effective use of elevators for evacuation during fire emergencies, especially for people with mobility impairments. The improvements identified in this section are based on perspectives from the study's participants and are intended to improve the ability of building occupants with mobility impairments to safely and comfortably use OEEs for evacuation during building fire emergencies. Improvements to evacuation planning and procedures (generally) as well as to existing elevators can be found in Butler et al. [10].

This study and the perspectives from participants highlighted the importance of reducing anxiety about fire evacuation and increasing trust in the OEE system via a variety of means, including education and consultation in preparation for the evacuation, information and attention to occupant needs while the evacuation is taking place, and two-way feedback and discussions afterwards. Key to all of these issues is the need to include those with mobility impairments in the planning and execution of fire evacuations, as well as in feedback sessions, and to facilitate their ability for self-evacuation as much as is practicable.

Prior to the occurrence of a fire emergency, education and consultation with people with mobility impairments regarding the OEE system should occur. The building can provide multiple means for education on OEEs for building occupants with mobility impairments, including allowing them to meet and talk with fire safety experts regarding the safety of these elevators. Comfort levels with the OEE system would increase if building officials (including trainers) can provide information on where and how OEEs have been used or practiced in fire emergencies, including examples of successful evacuations using these systems. Additionally, information could be provided on preventative maintenance of these systems. Finally, suggestions were provided by participants that, during education sessions, building officials, elevator manufacturers, or other knowledgeable officials could discuss the reliability of the elevator system and the back-up systems in place to make sure they run safely in case of power loss or other operational challenges.

In addition to preparation, participants suggested improvements to the information provided to occupants and attention given to occupant needs during the evacuation. Overall, communication is key during fire evacuation, especially evacuation via elevators. Participants suggested that they are provided with the ability to communicate with emergency personnel both while they are waiting for the elevator and while they are evacuating via elevator. In addition, timely information that supports decision-making should be provided, including the status of the fire (including location), what they need to do in response, the status of the evacuation (including which elevators are available for use at any time), and any updates on the fire and evacuation over time. To the extent practical, in addition to a telephone inside the car allowing for communication with the command center, a mechanism could be provided allowing the people inside the car to see that someone is located at the command center (available to answer if there is a problem).

Also, improvements to procedures were provided by study participants, mainly focusing on the issue of priority. When using OEEs for evacuation, preference should be given to wheelchair users and others with mobility impairments. In turn, building occupants able to negotiate the exit stairs should use the stairs until all those with mobility impairments have been evacuated. Possibilities for promoting this preference include the following:

- Use training to establish a building culture that encourages the use of OEEs during evacuations while preserving priority use by those with mobility impairments

- Post and repeat statements such as: “Thank you for keeping the evacuation elevators accessible to everyone” or “Reminder: During building evacuations the elevators are to be used primarily for people with mobility impairments.”
- Place someone with authority, such as a floor warden, in the lobby to enforce priority use by those with mobility impairments and to help with overcrowding issues.
- Consider reserving a time period in the beginning of the evacuation for people with mobility impairments only. During this designated time period, appropriate signage could state: “Elevators are in priority mode. If you can, please use the stairs.”

Following the fire event, it is essential that a debrief or after-action session take place to evaluate the preparation, emergency procedures and results from the evacuation. This type of feedback and discussion can occur both after an actual emergency as well as following a practice drill. This will enable people with mobility impairments to further comment on the event and make appropriate changes moving forward to increase their comfort level and safety in the use of elevators for evacuation in fire emergencies.

The disability community has adopted the saying, “Nothing about us without us” [23]. In the case of fire evacuation, this expression is particularly applicable. People with mobility impairments are aware that their evacuation options are limited. They have a unique perspective on evacuation issues due to their daily experiences as well as their enhanced vulnerability. The development of new procedures, technologies, and designs for response to fire emergencies, including the use of elevators for evacuation, will benefit from their voices.

CONCLUSIONS

Safe evacuation during a fire or other catastrophic event is crucial for the safety of the building’s occupants. Since the tragic loss of life in the World Trade Center disaster, efforts have refocused on the provision of safe and efficient evacuation procedures, especially for occupants who cannot negotiate exit stairs without assistance. Several evacuation options have been designed specifically for people with mobility impairments, including occupant evacuation elevators (OEEs). The purpose of this study was to provide guidance to assist designers, facility managers, and fire emergency personnel on how they might improve designs, technologies, and emergency procedures for safer evacuation of occupants with mobility impairments via elevators during fire emergencies.

Face-to-face interviews were conducted with 51 participants with mobility impairments working in buildings located in five major metropolitan areas within the U.S. The dual goals in this study were to gain an understanding of how building occupants with mobility impairments evacuate multi-story buildings during fire emergencies and to identify the concerns about using elevators during fire evacuations.

The results of this study identified important perspectives from people with mobility impairments on the typical evacuation methods currently used in U.S. buildings during fire emergencies, namely emergency stair travel devices and areas of refuge. Main issues with these methods include the loss of mobility device and the fear/anxiety of being left behind, respectively. Benefits and concerns were also identified for passenger elevators, freight or service elevators, and OEEs. Overwhelmingly, study participants appreciated the independence provided by elevators during evacuation, and the ability to keep their mobility device with them at all times. However, the use of existing elevators did raise concerns about safety, crowding, lack of communication, wait time, and lack of priority use. While the presentation of new OEEs and its technology did seem to negate many of these concerns, issues with priority and overall trust in the reliability of the system still remained.

A discussion of improvements to OEEs highlights the importance of reducing anxiety about fire evacuation and increasing trust in the OEE system via a variety of means, including education and consultation in preparation for the evacuation, information and attention to occupant needs while the evacuation is taking place, and two-way feedback and discussions afterwards. Key to all of these issues is the need to include those with mobility impairments in the planning and execution of fire evacuations and to facilitate their ability for self-evacuation as much as is practicable.

Also key is the provision of OEEs as a safe and viable ***option*** for evacuation during fire emergencies. Any emergency procedures, training and education should make it clear that that elevators are one option for evacuation; however, not the only option. Back-up options will also exist, including areas of refuge as well as emergency stair travel devices. Building occupants with mobility impairments should be informed about these alternative evacuation options and allowed to provide input on all of them.

The results of this study led to guidance on evacuation planning and procedures, the use of existing elevators for evacuation of people with mobility impairments, and the use of occupant evacuation elevators during fire emergencies.

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