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THE USE OF ELEVATORS FOR EGRESS DISCUSSION PANEL

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BACKGROUND

As a result of the September 11, 2001 attacks on the World Trade Center, code provisions for emergency egress from tall buildings are being re-examined. There is a strong interest in the use of elevators for both occupant egress and firefighters access.

A workshop on the Use of Elevators in Fires and Other Emergencies was held on March 2-4, 2004, in Atlanta, Georgia. The workshop was co-sponsored by the American Society of Mechanical Engineers (ASME International), the National Institute of Standards and Technology (NIST), the International Code Council (ICC), the National Fire Protection Association (NFPA), the U.S. Access Board, and the International Association of Firefighters (IAFF).

The workshop focused on two general topics: (1) Use of Elevators by Firefighters; (2) Use of Elevators by Occupants during Emergencies. Plenary Sessions were organized during which selected papers were presented, as well as Breakout Sessions for attendees to brainstorm various ideas and develop recommendations. The goal of the workshop was to come up with concrete proposals that could be put forth to the various code-writing groups to help improve codes and standards. Following the workshop, the Workshop Steering Committee, which was made up of representatives from each of the sponsoring organizations, met to review these proposals and assign issues to the appropriate organization for consideration.

It was decided that the American Society of Mechanical Engineers (ASME International) through its A17 Committee formed two task groups. The Task Group on Use of Elevators by Firefighters and the Task Group on Use of Elevators for Occupant Egress.

It was recommended that the Task Groups engage in the following tasks:

1. Review the suggestions from the Workshop on the Use of Elevators in Fires and other Emergencies.
2. Develop a prioritized list of issues that the task group members want to pursue.
3. Conduct a hazard analysis of the prioritized list of issues to find any residual hazards.
4. Draft code revisions for those issues that survive the process and the task group members still want addressed.

Each of the Task Groups began reviewing the issues at the first A17 meeting in February 2005. In the fall of 2008 the first three tasks of the Task Groups were essentially completed. Drafting code revisions should start in 2009.

Meanwhile, the use of elevators or lifts for egress is gaining acceptance around the world. A few buildings are now equipped with elevators that are expected to be used for building evacuation such as, the Stratosphere Tower in Las Vegas, the Shaft in London or the Eureka Tower in Melbourne. It seems, however, that several issues are still open for discussion.

PANEL

A panel discussion on the Use of Elevators for Egress is very timely as more and more prestigious buildings are contemplating using this equipment to manage a safe and rapid evacuation of their occupants. It is also likely that this approach will be considered more and more for buildings of different sizes and occupancies as the population is aging, and limitations and overweight are becoming prevalent in developed countries. If elevators become a common means of egress this will change the entire face of fire safety. Much work seems to be needed before we get there.

Each panel member has been selected for their specific expertise and represents a leading figure in their own field.

EMMA HEYES:
OCCUPANT RESPONSE

For the use of lifts for evacuation to be successful, engineers will need a solid understanding of how building occupants are likely to behave when given the opportunity to evacuate using lifts. This will allow engineers and building designers to develop appropriate evacuation strategies and make realistic design assumptions. In addition, engineers and those designing lifts for evacuation should consider how to encourage occupants to behave in a manner that will result in the most efficient and safe evacuation for all. Unfortunately, as this is a new technology, there are a number of gaps in our understanding of how occupants are likely to behave.

WHAT INFORMATION IS REQUIRED?

There are a number of areas where further research is required to fully understand how occupants are likely to behave in a building evacuation using lifts. The following questions are yet to be fully addressed by researchers into this area. It is considered that the answers to the following questions are critical to be understood for building designers and engineers to be able to design an optimal evacuation system.

- How can the 30-year campaign warning occupants not to use lifts for evacuation be overcome?
- What percentage of building occupants are likely to choose to evacuate a high rise building using the lifts in a fire event?
- How does this percentage change with the floor level that occupants are on?
- How can we overcome the possible problems of confusion if lifts can be used in some buildings and not others?
- How can overcrowding of the lifts be avoided?
- How many people are likely to fit in each lift car? Can it be assumed that lifts will operate at their design capacity in a fire?
- How will occupants react to the requirement to wait for some time for the lifts?
- Will lifts attend to the disabled population before the rest of the population? If so, how do we ensure that those occupants that most need to use the lifts (i.e. occupants with disabilities) are prioritized? Who decides which occupants need to be prioritized?

- Will social groups attempt to stay together during the building evacuation, or will they be prepared to separate to take different lifts? Will this lead to inefficient loading of lift cars?
- How will a lift evacuation system deal with stragglers, or with occupants reaching the lift lobby at different times due to varying pre-movement times?
- How will realtime information received from blackberrys, cell phones, internet or media coverage influence the behaviour of occupants?
- What concerns do building occupants have about using lifts for evacuation?
- How can building occupants be educated about the availability of lifts for evacuation, and how can designers and owners increase occupants' levels of trust in this new technology?

WILL OCCUPANTS BE PREPARED TO USE LIFTS FOR EVACUATION?

Following years of training not to use the lift to evacuate a building in the event of a fire, and the deaths of occupants that have attempted to use lifts to evacuate, it is conceivable that building occupants may be reluctant to use lifts in an emergency. Research suggests that many people currently perceive lifts for evacuation having a lower level of safety compared to the alternative, the fire-isolated stairs[1]. However, it is considered that this reluctance to use lifts will be surmountable on the basis of research that has been carried out into this area and the adaptability of people to new technologies.

In a number of past fire incidents, lifts were used by occupants to evacuate the building, even though they were not specifically designed for this purpose. The use of lifts in fire events where the occupants were trained not to use them suggests that there is a portion of the population who is already prepared to use lifts in an emergency event, and this percentage is likely to increase with specific training[2]. These events included the Chicago Cook County Building Fire (2003), the World Trade Centre collapse (2001), the Hiroshima Motomachi high-rise apartment building fire (1996), the fire at the Düsseldorf Airport (1996), and many others.

NIST carried out interviews with employees at 13 air traffic control towers in the mid-1990's to determine whether occupants would be willing to use lifts for evacuation. It was found that nearly all those interviewed expressed a strong preference for using stairs as the first choice escape route[3]. However, occupants did indicate that they would use lifts if required, but the level of hesitation and concern over using the lifts varied significantly between respondents.

Many respondents to surveys carried out as part of work done at the University of Canterbury indicated that they would be prepared to use the lifts to evacuate from a high-rise building in an ambiguous emergency situation[1]. However, there were a number of respondents who indicated that they would strongly prefer to use the stairs to evacuate even from the 60^{th} floor. It can be expected that there will be individual differences between the preferences of people to use one evacuation method over another. This should be taken into account when designing evacuation strategies, and it is considered unrealistic to expect that all occupants from the upper levels of a high-rise building will use the lifts.

Determining the ratio of occupants that will use lifts in preference to stairs is critical for building designers to understand so that they can ensure that the ratio of stair capacity to lift capacity is optimal to reduce evacuation times. Intuitively, and confirmed by some data[1], it can be expected that with increasing floor level, more people are likely to use the lifts. However, due to the influence that the context of the situation will have on the percentage of occupants choosing to use either the lift or stairs to evacuate, it is recommended that building designers run a number of sensitivity cases when evaluating the overall evacuation time of a building to determine the effect of the exit choices of occupants changing.

FACTORS AFFECTING THE USE OF LIFTS FOR EVACUATION

There are a number of factors that will affect the number of occupants that choose to use a lift to evacuate in an emergency situation. These factors may be due to individual differences between occupants (such as knowledge of evacuation routes, previous experiences of building evacuations, need for control etc), building or organisational factors (such as reliability of lifts on a day to day basis, effectiveness of emergency training etc), or situational factors (such as type of emergency, location of fire etc).

It appears that a primary factor governing evacuation choice between the lift and the stairs may be an occupant's estimate of the fastest evacuation route[1]. This preliminary research suggests that this is a greater consideration than the safest or least risky evacuation route. This may mean that one way of increasing the efficiency of an evacuation system is to have dynamic signage on each floor, indicating the likely evacuation time via both the lift and the stairs so that occupants can make an informed decision.

The concerns that people have about using either the lift or the stairs to evacuate seem to be universal across different population groups tested in Australia, New Zealand, Singapore and the USA[1]. The main concerns about using the lifts that respondents consistently cited were that they could be trapped in the lift, that there could be a power failure, having to wait too long for the lift, that fire or smoke could enter the lift, that one of the components of the lift would fail and that the lift car could fall. It is considered that these potential hazards are already being addressed in the engineering of lifts for evacuation, but that the mitigation measures and safety features of lifts for evacuation may need to be communicated to the public for them to trust this new technology and to understand why lifts can be used in some buildings and not others.

CONCLUSION

Overall, there is currently some understanding of the likely occupant response to the use of lifts for evacuation, but there are a number of questions that need to be answered before we have the full picture. Furthering our knowledge in this area will allow more realistic design assumptions to be used and more efficient and effective evacuation methods to be developed.

GLEN HEDMAN:
ELEVAOR USE FOR EGRESS BY INDIVIDUALS WITH DISABILITIES - CHALLENGES FOR THE DESIGN COMMUNITY

Possible use of elevators for egress during emergencies has received much attention during the past several years, as a component of overall evacuation strategies for building occupants. For individuals with disabilities, as occupants of elevator-equipped buildings of any height, use of elevators may represent the most efficient, and in some cases the only, means of egress. Use of elevators by individuals with disabilities will present several challenges to members of the design community. Aside from the performance requirements for the elevators, other aspects of the environment and possible users must be studied.

While initial attention has been paid to the use of elevators in office high-rises, designers should think broader in terms of the types of occupancies and ability range of occupants. Several factors combine to encourage a broader perspective. First, high-rises are increasingly designed to be multi-use buildings, with retail, office, and residential floors. Second, municipalities often have requirements for a percentage of the residential units of planned developments to be accessible. Third, there is a significant movement away from institutional care to community-based living arrangements for individuals with severe disabilities. So the occupants of high-rises might include residents with disabilities, who may have very different abilities than individuals employed on an office floor.

All aspects of evacuation travel by individuals with disabilities require attention.

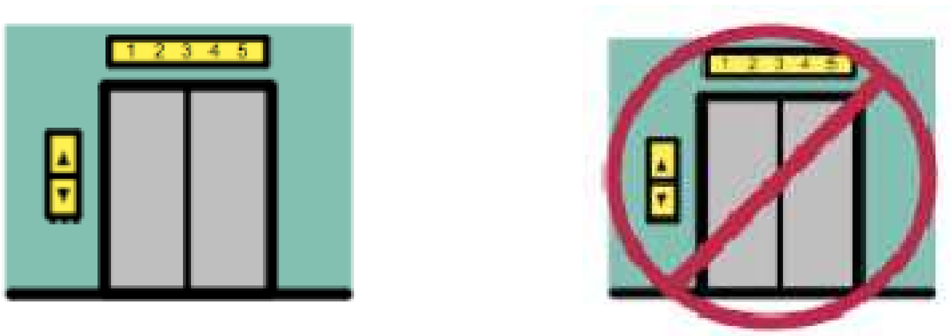
Regarding the time which passes between the sounding of an alarm and initiation of evacuation travel, individuals with disabilities have several unique factors which come into play. Individuals with disabilities must consider whether to pack up aids which may be needed if return to the office is not possible for an extended time. They must decide whether or not to take items that may include assistive technology devices, clothing which may be needed to address the current weather, service animals, and medication.

Travel by individuals with disabilities along pathways typical of those which might be present from their office or residence to the elevator lobby has received some attention. Boyce[4, 5, 6, 7] studied the travel of individuals with disabilities along horizontal and ramped straight surfaces, through doorways having doors equipped with self-closing devices, and turns. Rubadiri[8] also examined travel along pathway elements by individuals with disabilities, and factored in the use of different mobility aids to indicate an influence on travel times. More research is needed in this area, however, to build a database regarding the speed of travel of a larger sample of individuals with disabilities. A wide range of travel speeds exists, from those traveling slower than standard ambulation (e.g., users of canes and walkers) to those traveling faster (e.g., users of powered mobility bases).

Once at the elevator lobby, situation awareness issues exist for individuals with disabilities, as they do for all occupants. Beyond the issues common to all occupants, issues exist regarding the type of information presented, and the format used.

The use of icons to communicate whether or not elevators are available for evacuation for a given floor will not only address the issue of different languages being spoken by building occupants, but also assist in communicating the information to individuals who communicate primarily through symbols instead of the written word. Figure 1 shows the "elevator" icon of a communication aid symbol set; and on the right an adapted version. Would these be recognizable to all building occupants? Or are there generic elevator symbols which can be readily understood by individuals with disabilities? To design the most effective icon system, individuals with disabilities and professionals who design communication systems for these consumers need to be included in the design process.

Figure 1. Elevator symbol which may be used by individuals who use a communication aid, on the right Elevator symbol adapted to signify "Do Not Use Elevator." (Picture Communication Symbols (PCS™), by Mayer-Johnson, LLC).



Size of images and lettering needs to comply with applicable codes. For instance, the Americans with Disabilities Act Accessibility Guidelines requires a character height of 51 mm (2 inches) when the characters are 1780 mm (70 inches) to 3050 mm (120 inches) above the finished floor, and viewed from a horizontal distance of less than 4570 mm (180 inches).

Clearly, research is needed in this area, to determine the best combination of elements which convey the message about the evacuation options. It appears that elevator design is on a track to bring elevators into play during an evacuation. Research work on the optimal design for real-time signage and voice notification systems which will be part of the environment must start, and yield results which can provide specifics for these components. If it does not keep pace with the elevator code work, systems will be implemented which may not perform as well as they should.

It must be recognized that the best, inclusive effort on the part of the design community is only part of the solution. An evacuation plan which is developed with the participation of individuals with disabilities, thorough training of all building occupants and compliance during an evacuation drill or event is essential.

JASON D. AVERILL:
TIMING OF ESCAPE - STAIRS VERSUS ELEVATORS

Efforts to use the egress capacity of elevators for escape from buildings during fire emergencies have been ongoing for several decades. In 1974, Bazjanac proposed using elevators to evacuate during fire emergencies[10] and presented calculations in 1977.[11] The NFPA Life Safety Code (LSC) considered the problem in the 1970's, including the generation of a detailed list of problems with using the elevators as fire exits.[12] The LSC Subcommittee on Means of Egress subsequently passed elevator egress provisions in the late 1970's (Section 5-12 proposal), but the action was overruled by the assembly at the annual meeting.[13] In anticipation of the Americans with Disabilities Act, the NFPA, the ASME, and the Council of American Building Officials (CABO) sponsored a symposium on elevators and fire in Baltimore, Maryland in 1991.[14] NIST held a workshop in 1992 with the research community and elevator industry.[15]ASME hosted a follow-up workshop in 1995.[16] Finally, a collaborative effort between ASME, NIST, ICC, NFPA, U.S. Access Board, and the IAFF in March 2004 resulted in task groups developing technical requirements for occupant and firefighter use of elevators during fire emergencies.[17] In the 30+ years of work, the effectiveness of using elevators for reducing overall building evacuation time has been immediately recognized at every workshop; the focus has been on ensuring that the procedures and technology are robust enough to maintain or improve the safety record of using stairs during a fire emergency. This paper will assume the procedures and technology are effective and review the quantitative advantages of using (i) only stairs, (ii) only elevators, and (iii) elevators with stairs.

Elevator Movement

The design parameters for elevator performance are generally driven by consumer expectations; in other words, people have an expectation that they will not wait a long time for an elevator to service their request. As the peak periods of elevator usage in commercial office buildings (morning rush as people arrive and "quitting time" as people leave) are similar to the service demands expected during a fire emergency, it is assumed that there is sufficient existing capacity in most tall buildings to effectively conduct building evacuation with elevators. Strakosch[18] published a text on the design and performance of elevators, including movement parameters. Based on the "quitting time" calculations from Strakosch, Klote, et al., published simple algorithms for calculating evacuation time by elevator (shown in Eq. 1);[19]an electronic tool (Elvac) remains available in electronic format.[20]

$$t_e = t_a + t_o + \frac{(1+\eta)}{J}\sum_{j=1}^{m} t_{r,j} \qquad [1]$$

Where $t_{r,j}$ is the time for round trip j; m is the number of round trips; J is the number of elevators; η is the trip inefficiency; t_a is elevator evacuation start-up time; and t_o is the travel time from the lobby to the outside or other safe location.

As a simple bounding case, elevator industry representatives suggest that elevator capacity is generally designed to move approximately 13% of the building population in a five minute period (depending upon the specifications of the building owner). This would translate to moving the entire building population in roughly 40 minutes for most buildings. For additional data and analysis, a collection of over 40 research articles on elevator evacuation was made available by Bukowski, et. al. at http://wtc.nist.gov/pubs/elevators/index.htm.

Stair Movement

Nelson and Mowrer[21]review the standard methods for estimating occupant movement speeds down stairs. Every major evacuation model will also produce estimates of building evacuation time, including stair descent.[22] A final note on timing of stair evacuation: a "rule-of-thumb" used by the US fire service for low- and mid-rise buildings is that total building evacuation by stairs will take approximately one minute per floor to complete. This estimate may not apply as well to large footprint or ultra-high-rise buildings, and the limitations of this approach are apparent in Table 1.

Mixed Elevator/Stair Movement

Combining the use of stairs with elevators should produce the optimal evacuation time for a building. In general, occupants low in the building will evacuate faster by using the stairs than waiting for elevators and occupants on upper floors in tall buildings will evacuate faster using the elevators. Klote, et al evaluated four office buildings in the early 1990's[23](summarized by Kuligowski and Bukowski, 2004[24]), quantifying the benefits of mixed-mode evacuation for a range of building heights using Elvac and the method of Nelson and MacLennan described above.

Table 1: Computational Estimates for Building Evacuation Time (Klote, et al)[23]

Floors	Stairs	Elevators	Population	Stairs Only (min)	Elevators Only (min)	Both (min)
7	6	6 groups of 2	3,621	7	17	6.3
13	2	2 groups of 5	3,506	14.9	24.3	11.2
18	2	1 group of 4	1,425	14.3	28.6	12.0
36	2	3 rises of 6	3,021	23.1	16.5	12.8

In addition to computational analysis, reported evacuation time data from Taipei 101 showed the significant improvement in overall building evacuation time when comparing stair-only evacuation time to stair-elevator evacuation time. An evacuation drill using the stairs took approximately 2.5 h to complete. After incorporating protected elevators for egress from the upper floors, the building evacuation time was reduced to less than one hour.[25]

Conclusions

For taller buildings, elevators can provide significant potential for reducing overall building evacuation time over the traditional stairs-only approach. Overall building evacuation times of 1 h or less may be achievable with stairs in buildings up to approximately 50 stories and with a combination of protected elevators and stairs for buildings of significant height, without increasing the number or size of the stairs or elevators above current practice.[26]

JAKE PAULS:
HUMAN FACTORS IN EGRESS BY ELEVATORS

The following remarks are based on 42 years as a student of means of egress in research and consulting roles mostly in the USA and Canada, with enough overseas involvement to be accustomed with both "lifts" and "elevators" to discuss their increasingly important role in egress. While most of this career has focused on use of stairways, there has been an interest in elevator/lift use for egress that dates back over three decades, including presentations and papers such as the following (which, except for the 1977 paper, are available for free downloading, as PDF files, from the Downloads area at http://web.me.com/bldguse).

- "Management and movement of building occupants in emergencies," Second Conference on Designing to Survive Severe Hazards, Chicago, 1977.[27]

- “Elevator use for egress: The human-factors problems and prospects.” Symposium on Elevators and Fire, Baltimore, 1991.[28]
- “Elevators and stairs for evacuation: Comparisons and combinations. Workshop on Use of Elevators in Fires and Other Emergencies, Atlanta, 2004.[29]
- “Ergonomic considerations in use of elevators for occupant evacuation of buildings.” 16th World Congress of the International Ergonomics Association, Maastricht, 2006.[30]
- “Selected Human Factors Aspects of Egress Systems Design.” CIB TG50 & W14 Joint Symposium on Tall Buildings and Fire, Atlanta, 2006.
- “Implementing the paradigm shift to use of elevators/lifts for occupant evacuation of buildings.” Include 2007, The Helen Hamlyn Research Centre, London, 2007.[31]

To give some favor for the conclusions expressed in the papers, here are selected excerpts, presented in chronological order. “It must be stressed that no general recommendation for use of elevators in emergencies is implied. In view of the problems that have occurred with elevators in building fires their use requires careful consideration and approval by authorities. This hypothetical example is given only to illustrate some of the problems and some of the potential solutions.” [27]

“It should be clear that, to some extent (and perhaps especially in North America), an attitudinal turn of 180-degrees is required to implement the recently proposed or adopted measures formalizing use of elevators for egress by persons unable to use stairs. Long-held attitudes might well turn out to be a bigger impediment than the technology needed (and largely available) to make elevators relatively safe in many fire conditions and to make the options known to building occupants plus the fire services before and during a fire emergency. . . Of course some of the reticence about elevator use in emergencies is warranted. Other than in Britain, little has been done to even outline, let alone detail, the operational aspects of refuge and the combinations of stair and elevator egress.” [28]

“. . . our engineering efforts need to include *human factors engineering* or *ergonomics*, especially to address the operation of systems whether they be stairway systems or elevator systems, . . . Much more attention needs to be given to these issues and it is hoped that the third of the focused meetings on use of elevators in fires will provide a good opportunity for the necessary open-minded, interdisciplinary discussion.” [29]

“A paradigm shift, resisted for decades, occurred in March 2004 after an international workshop on use of elevators during fires in buildings. . . the paradigm shift was a widely supported decision to move toward use of elevators for evacuation of building occupants in fires. Subsequently, a series of working meetings was held to conduct multidisciplinary hazard analyses by task groups organized by the American Society of Mechanical Engineers, the secretariat for the US national elevator standard, ANSI/ASME A17.1. Numerous ergonomic (human factors) issues are raised but they are not yet well addressed. Issues include staffing, training, signage, communication, systems operations and, most generally, how to both transition from—and co-exist with—traditional exit stairway-based systems for occupant egress from buildings. Within several ASME-hosted working meetings to date, the hazard analyses have identified, in an iterative fashion, numerous hazards, causes/triggers, incidents/effects, corrective actions and residual hazards. Key to a balanced completion of the hazard analysis process—and standards revisions and eventual implementation in actual buildings—is greater participation of ergonomists so that not only can human capabilities be fairly addressed, but vulnerabilities of other system components can be identified as well. . . The authors believe a failure to adequately address the critical human factors will be an Achilles’ heel in the paradigm shift toward use of elevators for occupant evacuation. This message is to be delivered in the ASME task group and other code-development deliberations during 2006. . . It is hoped that . . .more ergonomists become involved in this highly interesting and important field.” [30]

“Generally if we are to accomplish the paradigm shift, to provide elevators usable for occupant evacuation, we need to invest in testing and evaluation. This model stressing—*planning,* *implementation and evaluation*—is NOT used in the building industry. The consequences of not doing this well will be catastrophic." [30]

"In terms of human factors or ergonomics challenges, there is good agreement that availability of relevant and accurate information is a key aspect of egress, especially if it entails use of lifts. Thus there should be increased discussion of "situation awareness" generally in our work on building design, operation and emergency response. Good situation awareness means having the information that gives one the best basis for determining current and future actions. Thus, aside from having effective means of communicating relevant information, we need to consider attitudinal factors that will influence interpretation of information. . . One encouraging point is that, emergency behavior is strongly influenced by what is familiar (a point demonstrated in the emergency behaviour work of the late Jonathan Sime), thus movement to the lifts—and their use—is to be expected when one has to escape in an emergency. Lifts do not need to found in the same way that exit/escape stairs need to be found during an emergency. Furthermore, as we integrate lifts and stairs, both in a building layout sense and in an operational sense, we will make both more effective. . . Confusion about appropriate emergency measures among ordinary building occupants, as well as facility managers, emergency responders and others must be effectively mitigated if not prevented during the transition to the new paradigm. The needs for the new paradigm are varied, the problems to be solved great, the benefits real, and the downside risk substantial." [31]

DAVID MCCOLL:
USE OF ELEVATORS FOR EGRESS

The following commentary summarizes the work of the ASME A17 Code Task Group on Use of Elevators for Occupant Egress and the North American Elevator Industry position on this topic.

The A17 Task Group has been following a process to review the suggestions from an ASME Workshop held in March 2004. The Task Group has developed a prioritized list of issues, conducted a Hazard Analysis of the issues and will be drafting code revisions or recommendations. The recommendations are sorted by Code type: Elevator, Building, Life Safety, Electrical, Accessibility and Firefighters' issues.

The task group has been meeting for over four years, usually four times per year for two days at a time and has performed extensive Hazard Analysis of the issues. The analysis is essentially complete but recommendations are not fully developed.

The initial Hazard Analysis has been an investigation of the use of elevators during emergencies for evacuation of occupants in an occupied high-rise office building, prior to activation of Firefighters Emergency Operation Phase I emergency recall operation. An assumption we made in our Hazard Analysis is that corrective actions involving occupant behavior should be evaluated with representative populations before codifying. However, we have not yet determined how this assumption will be implemented. A sub-group consisting of some of the members of our Task Group who are also members of this panel has been formed to review the hazard analysis to evaluate the cases incorporating assumptions pertaining to occupant behavior. This sub-group will give some guidance on the further work or research needed to confirm the assumptions. Situation awareness pertaining to all of the relevant issues, such as capacity, design of signage/voice, use of wardens and training has been ongoing throughout the analysis.

A new operation called EEO (Emergency Evacuation Operation) has been proposed which would provide elevator operation for egress from five affected floors (the fire floor, the two floors above and the two floors below the fire floor) to the designated (main) level.

Extensive signage and tenant training will be necessary in order to facilitate the new operation and allow passengers to adapt to a new paradigm, which in the past has been, "In Case of Fire, Elevators Are Out of Service". "Real-time" signage on all floors would be needed to inform people whether or not to use the elevators on a given floor. Signage at the main lobby landing would be provided to advise people to not use the elevator. Signs in the cars will give passengers instructions. There will be "Real-time" voice announcements to elevator lobbies and cars. In addition, building occupant training and drills, supplemented by use of floor wardens during the emergency will be necessary.

New building enhancements will also be necessary and the task group will be making recommendations to the building code writing organizations for such building features as: protected lobbies and stairwells, pressurized hoistways, lobbies and stairwells, provision of a fully sprinklered building, a full building smoke detection/evacuation system and protected normal and emergency power to elevators and signage/voice systems.

Although the Task Group has not completed its Hazard Analysis process yet, it expects the code writing phase to commence in 2009, with recommendations being formulated for the Elevator, Building and Electrical Codes and for firefighters' organizations. Some of the other issues under analysis include: seismic activity; full building evacuation; Sky Lobbies; unique building configurations and other types of occupancies and monitoring, maintenance and inspection issues.

The Elevator Industry in North America, represented by National Elevator Industry Inc. (NEII), is supportive of the study of the potential for Occupant Evacuation elevators to be used as a secondary means of egress prior to automatic Phase I operation.

NEII believes that where requirements for Occupant Evacuation elevators are included in model building codes, they should include elevator operation from the five affected floors to the designated level on all passenger elevators along with the real-time signage on floors and in elevator cars, accompanied by voice announcements. These features should be initiated by intervention external to the elevator controls, but may include elevator input. In addition, these elevators need to have protected power feeders, protected lobbies, pressurized hoistways, lobbies and adjacent stairwells and full building smoke detection/evacuation and sprinkler systems.

NEII also believes that training of firefighters in use of elevators on Firefighters' Emergency Operations and Occupant Evacuation elevators will be critically important as will occupant training, fire drills, and floor wardens provided by building management.

NEII does not support:

- Reduction of exit stair capacity where Occupant Evacuation elevators are provided;
- Water resistant elevators. Water resistance during the life of the installation cannot be assured. The preferred approach would be for the building code to prevent water flow into the hoistway.

PETER JOHNSON:
AN INTERNATIONAL PERSPECTIVE

From an international design perspective, it is evident that the use of elevators for egress is increasing and there is growing interest from developers, designers and owners/ tenants. Projects in East Asia, Europe, the Americas and Australasia show this approach to egress capturing design attention.

The key drivers for this interest are:

- Increasing desire of developers for taller buildings, within some current designs over 1000m high
- Demographic changes with ageing populations and greater obesity leading to issues of fatigue
- An increase in many different forms of disability, making use of stairs impossible or problematic for some persons (now greater than 20% considered disabled in Australia)
- The need to provide safe, equitable and dignified egress for all building occupants under occupational health and safety legislations (OH&S)

- In the event of non-fire threats, desire for more rapid evacuation of a building overall for non-fire threats using elevators and stairs in combination, particularly since 9/11
- A design ambition to better rationalize protected fire fighter access and occupant egress.
- Child care centres in Australia located on upper floors of multi-storey buildings.
- In selected cases, such as Los Angeles a move away from roof top egress by helicopter.

DESIGN CONCEPTS

There are two different design concepts for egress using elevators, namely:

- Transfer/ refuge floors- in this concept, building occupants travel down the stairs to a protected transfer/refuge area and then travel by shuttle elevator to the ground.
- Direct evacuation – in this case, building occupants enters a protected lobby and directly into the elevator at each floor.

If elevators are used to evacuate all occupants, then theoretically the width of stairs could be reduced. However, there is little evidence to date that such reductions in new building designs are occurring, presumably due to conservative design, approval authority resistance, and a desire to reduce the overall time for building evacuation using stairs and elevators in combination. What is evident, is that the use of transfer/ refuge floor concepts are the most popular, and direct evacuation into elevators at each floor of a building is the exception.

CODES AND STANDARDS

The design of buildings with egress by elevators, at least by disabled persons, has been set out in a British Standard BS5588-8 since 1999.[32] More recently, changes to the International Building Code (IBC)[33] have set out requirements for use of elevators for egress, and there is an "Emergency Evacuation Elevator Systems Guideline"[34] published by the Council on Tall Buildings and Urban Habitat (CTBUH).

These standards and guidelines highlight a range of building features which must be provided if elevators are to be used in conjunction with stairs in a safe manner for egress. These features include:

- Building sprinklers
- Protected lobby and pressurization
- Lift shaft (hoistway) structural stability
- High reliability power supplies
- Two-way communication systems in elevators and lobbies
- Protected wiring and cables
- Sloping floor and other measures to prevent water damage to elevator controls

It is clear that the engineering design of elevators for this application is well developed and understood by many designers. The challenges are in occupant behaviour, fire safety management, training and education and general event preparedness.

PROJECT EXPERIENCE

The use of elevators for evacuation has been implemented in a range of buildings, some in design but many built or in construction, and many of them the tallest buildings in the world. These include:

- BT Tower, London
- Stratosphere Tower, Las Vegas
- Shanghai World Financial C entre, China
- Burj Al Alam, Dubai
- Kingkey Financial Centre, Shenzen, China
- Burj Dubai, UAE
- The Shard, London
- Petronas Towers, Kuala Lumper
- Eureka Tower, Melbourne
- Pacific Red Building, Los Angeles

Most of these buildings use the transfer/ refuge floor concept.

There is also a level of interest in use of elevators for evacuation in lower rise buildings in Australia, with multi-storey hospitals now being designed in Perth and Melbourne with horizontal exits and use of elevators to avoid the risk of taking patients downstairs.

CHALLENGES

The real challenges come in the behavioural response of occupants to the use of elevators together with stairs for egress in real emergencies. Research analysis has suggested that use of elevators and stairs reduce the total building evacuation time by 30-40% over use of stairs only. [35, 36]

However, key questions remain to be fully answered. These include:

- How much and what type of training is required for building occupants in a new building designed for use of elevators for egress? (especially given a lifetime of training of people to avoid elevators in emergencies),
- Given recent research in Australia by Manly[37] that suggests people are becoming more reluctant to be fire wardens and get involved in evacuation drills, how will successful fire management teams work in the future?
- What factors will influence occupants to use elevators or stairs in different types of emergencies in the most efficient manner
- Will the disabled, aged, obese or other occupants feel inclined to use elevators in a large fire situation? (or would they prefer a defend in place approach?)
- Are we sure that our complex building and communication systems are up to the task of working correctly at higher reliability?
- Do we need to override elevator loading systems, car door safety edges and other controls to obtain maximum efficiency with use of elevators in emergencies?

Practice in the UK[38] for one major tower building suggests that very forceful fire wardens/ marshals, together with loud attention seeking messages, are required at elevator cars to ensure efficient usage of elevators and stairs.

CONCLUSION

Fire engineering design aspects of use of elevators together with stairs for egress is now fairly well established and a number of major buildings have been designed and constructed in this manner. Further research is required on those human behaviours and management in use aspects, together with training and signage if the use of elevators for egress continues to develop as a viable design option, and a safe means of evacuation.

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