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ENHANCED ELEVATOR OPERATION DURING EMERGENCY CONDITIONS

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Abstract

The complex issue of occupant safety in buildings during emergencies has been the subject of debate amongst enforcing authorities, building owners, emergency personnel and code bodies for many years. The tragic events of September 11th 2001 have added to the urgency for developing solutions that will enhance occupant safety.

The elevators are the primary means of vertical transportation in most buildings and potentially can play a vital role in the event of an emergency. The dominant practice around the world, however, is to discourage the use of elevators by the public during these emergencies, except when the elevator is under the control of qualified emergency workers, such as firefighters. The major reason for this practice is the unpredictability of the emergency (e.g., fire) and the added danger of entrapping passengers in the elevators due to the emergency condition.

As part of a broad safety evaluation by all stakeholders in the building industry, the elevator segment is exploring the potential for enhancing the role of elevators in emergency circumstances. The potential for building emergencies is global in scope, and it is therefore appropriate that this important issue be examined in a worldwide context. Two ISO committees, TC 92 and TC 178 are concerned with building evacuation and the role of elevators during emergencies. TC 178 has commenced a risk assessment from an elevator perspective, which is intended to identify hazards likely to be encountered in various types of buildings during various types of emergencies.

Mitigation of the hazards will result in potential functions that could be performed by the elevator for a given building type and hazard encountered. The result will include issues such as emergency power requirements, equipment vulnerability and resistance to hazards such as fire, smoke, heat and water. In anticipation of the results, initiatives are in process to identify the information necessary from other building systems, to allow for enhanced elevator operation in emergency conditions.

Key words: *Elevators, Elevator emergency operation, Fire Fighters Lifts, Building Evacuation, Risk Assessment*

1. Current Elevator Functionality

The current function of elevators installed in the U.S. during a fire-related emergency is predicated on certain fundamental assumptions.

- Due to unpredictable nature of fire propagation, elevator reliability cannot be assured.
- Smoke propagation and accumulation is unpredictable, thus the safety of passengers cannot be assured.
- The presence of water from sprinkler systems or fire hoses could disable elevators and entrap passengers.
- Human behavior during the emergency may be very different under various circumstances and is thus unpredictable.
- Power availability during a fire may not be relied upon due to possible damage to power feeders and associated equipment.

The protocol that has thus evolved, envisaged a scenario in which a building is fitted with a sprinkler system and smoke detectors, as well as emergency exits and staircases that are protected by fire-rated doors. In the event of a fire, a smoke detector on a floor in the affected zone, or other fire alarm device, would send all elevators immediately to the designated landing (this is usually the ground floor). If the designated landing were also a fire floor, the elevators would be recalled to a pre-assigned alternate landing. This operation in the U.S. is known as Phase I Recall Operation. A key switch in the elevator car, or at the Building Monitoring Station, if provided may also initiate phase I Recall Operation:

Emergency personnel may secure any elevator recalled under Phase I Operation by engaging Phase II Firefighters Operation, using an in-car key switch. Under Phase II Operation, the emergency personnel (usually firefighters) have complete manual control of the elevator; including the floors at which it stops, and the door operation. During Phase I and Phase II Operation, the elevator will not respond to hall calls.[1]

Thus in a typical scenario, if the fire occurs on one or more floors of a building, the fire alarm will alert the occupants. The occupants have become accustomed to the practice that in event of fire, they should use the stairways, not the elevators to exit the building. Warning signs in the elevator lobbies reinforces this practice. Able-bodied occupants would commence the process of leaving the building using the stairways. Disabled people and others who are unable to negotiate the stairs would assemble in hallways or fire protected areas to await rescue.

The building sprinkler system would typically function to suppress the fire. This would not, however, de facto eliminate the development of smoke. Phase I Operation would recall the elevators to the designated landing. When the Firefighters or other Emergency Personnel respond to the fire, they would assess the situation and strategize as to how the elevator should be used to rescue people at the location of the fire or elsewhere in the building, and/or to transport equipment to fight the fire.

The approach used in Europe generally requires that the elevators be recalled to the designated landing and shut down. Special dedicated firefighter elevators are provided for use by the firefighters for the purpose of transporting firefighters and equipment to the vicinity of the fire. Such elevators may also be used for rescue purposes by the firefighters.[2] Fire-rated doors typically in a fire-protected portion of the building, separate these elevators. The elevators are also constructed with water and heat resistant features, so as to be more reliable in the event of a fire. Firefighters elevators are usually small and limited in numbers to one or two in a typical building.

2. Realities of Current Operations:

While the logic of having elevators available to Firefighters and Emergency Personnel on Phase II Firefighters Operation is clear, the reality is that the Firefighters, when faced with pressure of an emergency, do not have a comprehensive assessment of the condition of the elevators, or the reliability of all the systems upon which safe operation of the elevators is dependent. Rather than risk using the elevators and being entrapped or, entrapping passengers, the firefighters will often use stairways for both rescuing people and fighting the fire. Many fire departments strategize their approach to a building with the assumption that the elevators are not available, and that the stairs, or ladders, have to be used as the prime means of approaching the fire. By strategizing ahead of time, valuable on-site time is not lost unnecessarily assessing the conditions of elevators. The Emergency Personnel often uses by exception rather than as a part of the plan for rescue and firefighting these elevators.[3]

In many buildings, the occupants/guests are not aware what action to take in the event of a fire or other emergency. While some buildings carry out regular "fire drills" and in some cases, training sessions, others rely on notices, signs or nothing at all. Thus in an emergency, people may panic due to lack of knowledge of what course of action to follow, or lack of information about the reality of the situation.

3. Concerns to be Addressed with Current Approach

In many situations, elevators, which have been recalled on Phase I Operation, are in perfect working order and could be safely used by the Emergency Personnel on Phase II Operation both to rescue people and to transport firefighting equipment to a location chosen to fight the fire. Moreover, the elevators could be used to rescue people with disabilities.

If comprehensive information regarding the technical status of each elevator and the building conditions at each floor were available, this would be of great value to the Emergency Personnel. Such information would include the location and extent of fires, the presence and content of smoke and fumes, the status of sprinkler systems, water discharging into the elevator shafts, the integrity of power supply systems, and essential elevator control systems. This and other building operations could be made available either directly to Emergency Personnel at the Building Monitoring Station or a similar central point at the designated landing.

4. Current Studies of Potential Role of Elevators in Evacuation

The potential for building emergencies is worldwide, and it is therefore appropriate that this vital matter be studied in a global context. International Standards Organization, ISO, committees are concerned with various aspects of building evacuation during emergencies.

ISO TC92 (Technical Committee 92) is concerned with buildings issues. Standards Committee 4 (SC4) of TC92 is charged with the particular matter of building evacuation. As a general approach, elevators were not considered as part of the evacuation strategy for buildings during an emergency. This is due to the fact that too many uncontrolled factors exist, such as those outlined in Section 2, above. There is, however, recognition by SC4 that elevators could play a significant role in the evacuation strategy, and a liaison has been established between ISO TC92/SC4 and ISO TC178/WG6 to further explore this.

ISO TC178 is concerned with elevator/escalator issues. Working Group 6 (WG6) is particularly concerned with the role of elevators during emergencies. This Working Group has representatives from approximately 25 countries. The membership represents a strong cross-section of elevator expertise from around the world, and also has representation from some firefighters. Comparison of current practice by the different countries represented by WG6 confirms that the conventional wisdom is to advise against the unsupervised public use of elevators during a fire condition. Evacuation under the supervision of firefighters/ emergency personnel who have taken control of the elevators (under Phase II Operation in the U.S. or using special dedicated firefighter elevators in other areas) has been considered a safe approach.[4]

The liaison between ISO TC92/SC4 and ISO TC178/WG6 and the participation of firefighters in the Working Group studies has been a very positive approach. Moreover, it symbolizes the need for a holistic approach to building design and evacuation strategy. Clearly, the firefighting community needs to be a part of any strategy that includes the public use of elevators for evacuation during an emergency. If, for example, members of the public become trapped in an elevator while attempting to self-evacuate, this could impose an added danger to firefighters/emergency workers who would be responsible for freeing the passengers. Moreover, it would dilute the efforts of the firefighters in their endeavor to rescue members of the public trapped in the vicinity of the fire. The hard-earned knowledge of the firefighting community is an essential part of a comprehensive approach to safe building evacuation.

Codes and Standards relevant to elevator operations have evolved taking into consideration such events as fire and earthquakes in areas of high seismic risk. Moreover, anticipated events as a result of unintentional human action have also been factored into Codes and Standards development. For the most part, damage and unsafe conditions as a result of deliberate human action have not been considered. The deliberate attacks on the World Trade Towers, of September 11, 2001, and other acts with similar intent have led to a review of the basic assumptions regarding emergencies in buildings.[5] ISO TC178/WG6 has initiated a comprehensive Risk Assessment intended to identify the risks related to using elevators for the supervised and unsupervised evacuations of people during fires and other emergencies.

The scope of the Risk Assessment Study will embrace various building types, including the differing combinations of high-rise/low-rise, accommodation buildings, commercial/office buildings, and healthcare facilities. A variety of causes of the emergency will be considered including fire, earthquake, sabotage and terrorism. The implications of fire, heat, smoke; water, structural damage and power availability will be considered in the study.

Risk Assessment Methodology ISO TS14798 will be used as a tool for the Risk Assessment Study.[6] ISO TS14798 is based upon ISO/IEC Guide 51, the base document for Risk Assessment Standards.[7] Adjustments will be made in the methodology to facilitate its use for situations, which include "deliberate acts". The methodology provides for the detailed analysis of specific scenarios. The process involves the identification of all hazards, causes and events associated with the scenario, and the establishment of the hazardous situations. Once each hazardous situation is established, the Risk Assessment Team assigns severity and frequency levels to the hazardous situation. The combination of severity and frequency classifies the risk, and depending upon the risk level, the risk is mitigated by taking specific actions until sufficient mitigation has occurred. In its present form, ISO TS14798 does not require mitigation of hazardous situations caused by a deliberate act (such as sabotage or terrorism). This portion of the methodology will be adjusted, for the purpose of this particular study, in order to allow the inclusion of hazardous situations arising from intentional efforts to cause harm. It is recognized that while the frequency of occurrence of major acts of sabotage or terror such as the attack on the World Trade Center is low, the severity can be extremely high in terms of loss of life and serious injury, loss and damage to property, economic and psychological damage. Since risk is a function of both severity and frequency, the overall risk could be significant and needs to be carefully studied.

The Risk Assessment will be carried out by multi-disciplinary, international teams, which will involve representatives from around the world. To expedite the process, teams based in North America, Europe, and the Asia-Pacific Area will conduct the initial Risk Assessment work, and then bring the preliminary results to the broader WG6 membership for deeper study. The work of WG6 will ultimately be subjected to the review and approval process carried out by ISO TC178, under ISO procedures. This process will leverage diverse international talent and provide opportunities for input from local studies by other organizations and bodies on related issues, (e.g., studies by organizations such as NIST, The National Institute of Standards and Technology).

The ultimate product of the Risk Assessment study will be an ISO document, supported by broad international consensus, which includes a set of recommendations which may be used for National Codes and Standards revisions or adoption, or which may be utilized directly in the development of evacuation strategies for buildings.

5. World Trade Center Response

The recent tragedy of the World Trade Center does point out some facts that must be considered in relation to the present emergency response functionality of elevators. These facts must also be assessed along with the desire to change the use of elevators for evacuation from large structures in light of the World Trade Center Towers collapse.

a) About 90% of the occupants evacuated from the World Trade Center Towers. This represents the majority of occupants who were below the impact floors. Most of the people on or above the impact floors perished in the collapse, due to compromised stairwells. The elevators to the upper floors (and the mid rise in one tower) were rendered totally inoperative due to the aircraft impacts. The hoistways were dramatically breached[5], and indeed no degree of elevator functionality changes would have altered the situation.

b) The evacuation process of the occupants was orderly and compassionate, (based on participant accounts); panic and violence were not evident. Many accounts emerged about people helping those with disabilities down the stairwells. In fact this process was only slowed by the presence of smoke and the fact that scores of emergency personnel were also using the stairs to ascend the World Trade Center Towers.

c) Consistent with local practice, the emergency personnel[5] used the stairs to get to the fires. This amounted to climbing 60 flights, in full fire gear carrying all required equipment. Elevators that were in operational states sat idle in the lobbies.

Conclusions that can be drawn from these facts:

i) The stairwells provided egress from the structures for those occupants below the impact floors, despite the fact that smoke did finally engulf the stairwells. Added to this evacuation, hundreds of firefighters were climbing up the stairs at the same time.

ii) The firefighters were trained not to use the elevators in an emergency, and their practice is not to use them even for equipment transportation up a building. This fact demonstrates the misalignment between code required elevator function in an emergency and the emergency response procedures for such structures.[3]

Two important questions arise from the World Trade Center in regards to the use of elevators to enhance occupant evacuation in emergencies.

What can be done to make the elevator the firefighters "Transportation method of Choice" for emergency use in a building?

Can more be done to locate and harden hoistways, stairwells and other required core facilities?

As the longer-term ISO TC 178 WG6 committee analysis proceeds, these questions can be evaluated for practical solutions.

6. How do we make the elevator a trusted means of transportation to emergency personnel in an emergency situation?

- This question stands out as the most urgent of issues requiring resolution. The reasons are:
- Lives can be saved by quicker emergency personnel transportation.
- Solutions can be implemented to various degrees on many buildings, regardless of age, type or size.
- Technology is available or being developed to support a multitude of potential solutions.
- There is a human need and willingness to promote solutions

The problem is predominantly one of coordinating the diverse stakeholders to reach consensus on an integrated solution.

Many jurisdictions do integrate elevator usage into the emergency response procedures[3]; this is not the case in some jurisdictions such as New York City. The rationale is "Although many fire departments routinely use elevators to provide better access in high-rise buildings, FDNY does not do this because there have been fatalities associated with doing this".[5]

The fact that New York, one of the worlds premier high-rise cities, does not include the elevators in the response procedures; and that different cities respond with different procedures; demonstrates the point that unresolved issues exist between the current building system operations and emergency personnel.

Probably the largest issue is the fact that an emergency worker has no way of knowing how long the elevator will remain operational. The elevator system is not configured to predict this, nor can the Fire and Life Safety (F & LS) control system predict when a fire is about to put the elevator in jeopardy. The entire extent of support afforded to the emergency personnel is typically voice broadcast contact on walkie-talkies between themselves. These voice systems can prove to be a frustrating method in a dangerous, ever-changing emergency situation.

It is clear that a safer approach of providing information to emergency personnel is needed.

7. The Elevator Car as a Monitoring System

The feasibility of using the elevator car as a moving monitoring center for building information requires assessment. In such a scenario the fireman steps into the elevator and plugs in a standard flat screen display that attaches to the car wall. The screen may be split allowing for multiple displays with touch screen functionality. In one window real-time video can be selected so that the firefighter can see up the hoistway with emergency lights that have lit up the usually dark space. The image on the screen rotates through a range showing the elevator lobbies the particular car serves and the machine room that controls the particular car. The firefighter can also see the power line runs supplying the system, which could be located within the lobby or hoistway views on the monitor. The display will let the firefighter know the status of primary power, emergency power and elevator-specific power. As a minimum, the firefighter will know that the elevator has sufficient power to proceed to the nearest safe landing. The fire fighter now has a visual understanding of the potential danger of using that particular elevator; it is no longer an isolated "black box".

The view of the lobbies will let the firefighter know if disabled individuals are waiting to be rescued. Another section of the screen can display the state of all fire, smoke and heat sensors, on the fire floors, at the same time the HVAC system overlays the present space temperatures on the F&LS system display. The firefighter can now determine via the real time video and the displays, the level of danger outside the elevator door on each floor, before ever reaching the landings. The firefighter can also now prioritize any required rescue of waiting disabled people in the elevator lobbies. Moreover, the firefighter could communicate with such stranded people.

At the touch of the panel the central command station can be viewing the identical display if support is needed.

Other vital information could be displayed such as

- Safe lobbies for disabled occupants with video
- Emergency messages from the central command center coordinating the emergency personnel.
- Alarms if the machine room temperature rises to a preset level, alerting the emergency personnel to impending danger.

Many communications networks can be considered for this purpose. BACnet and Lonworks are two widely employed networks for inter-operability of computer systems and broadband video has been employed for many years.

These types of functionality would allow the first responders the ability to have initial damage assessment and occupant rescue issues known on arrival at a building allowing for a knowledgeable assault on the situation. The emergency personnel now have a visual understanding of fire and smoke progression allowing instantaneous response to their particular situation. Most importantly, the firefighter is in control of this particular situation.

The challenge of these systems becomes more complex when the solutions need to be integrated back into current elevator emergency response situations. Today's elevator codes and features provide for a multitude of different operations depending on the type of emergency encountered.[1,8]

The list of functions that will shutdown an elevator is extensive. This is conservative operation to maintain the highest level of safety to the general public. Many items on this list could be "overridden" to allow for elevator operation in a degraded mode of some description, when the car is under control of emergency personnel. This can create a hazardous situation for some, yet may be life saving to the elevator occupants. The task of achieving consensus on this "Grey Area of Operation" will be a major challenge.

8. Hardened and Distributed Hoistways

Two possible solutions being considered for building construction are a single-hardened building core or several separate building cores.

In the case of a single hardened core, the building would be constructed with a highly reinforced central structure, which runs the full height of the building. All essential services and building infrastructure could be located within this core. The core could be compartmentalized within to provide additional redundancy of essential services. The elevators would be located within this reinforced core.

A variation of the hardened building core envisages a reinforced core protected by a co-axial protective outer core, the two cores separated by a space. The inner core in such an arrangement can be structurally and environmentally protected. Elevators operating within the inner core would be highly protected from a variety of emergencies and operate normally as long as the integrity of the structure is maintained.

Distributed cores would be strategically located to minimize the risk of all being disabled simultaneously, and these would house the elevators.

9. Hardened Elevators

In conventional buildings it is possible to make elevators more resistant to the environment by hardening elevators for emergency operation.
Such elevators can be hardened for:

Smoke:
- A 2-hour rated barrier for the hoistway
- Mildly pressurized hoistways in an emergency situation
- Fire protected elevator lobbies (per Section 2 above)

Water
The two areas of concern are the door and pit switches.
- Water in the hoistway. This amounts to managing water flow in the vicinity of the hoistway doors.
- Use of waterproof switches in the hoistway. This will require a code change for the door circuits.

Power
This is the most problematic and costly element to secure. All buildings of concern have emergency power systems. The problem is that in many installations the power is located at the building base, the elevator controllers of concern (and the machine) are located higher up in the building.

Power management and redundancy may be accomplished via a variety of methods.
- Multiple separated feeds for main power
- Emergency generators

Areas that need to be considered
- Power run up the hoistway
- Battery power in the machine room to provide full operation for a period of time
- Battery operation to attain the next serviceable landing

The battery operation could be restricted to designated elevators only, in a group providing further robustness to a "firefighters" lift. Significant work has been done on compact, high-energy density batteries, which could be utilized for emergency power to several elevators.

10. Availability of Elevators

One of the areas requiring special attention is the time from the emergency occurring and firefighter response. A number of elevators could remain in public use while others are released on Phase I Firefighters Service. The period of time immediately following the initiation of a fire will provide the best opportunity for safe elevator operation. As time passes, the more likely a fire will breach the hoistways or machine rooms.

If the condition of any of the elevators, the building structural interfaces to the elevator, the power supply system and other relevant building systems, as well as the environment is monitored by dedicated sensors, the information can be used to determine whether the elevator is safe for use, following the activities of a fire alarm or other emergency sensor. The elevator could be cycled once with the doors closed to ensure that it is safe for operation. The information could be communicated to the building occupants using audio-visual indication, provided that a reliable system could be provided. The elevators could be programmed to serve the emergency floors if safe to do so or, if not, to floors in close proximity. The audio-visual system could advise building occupants where to assemble in order to access the elevators. Such a plan would be more effective if trained "floor captains" were available on each floor to help direct, reassure, and organize people.

Elevators on Emergency Service could proceed non-stop to the designated landing once filled, using a signal from the load-weighing system. Moreover, the elevators could still be recalled by the First Responders when they arrive using Firefighters Service Phase II in the U.S. or a similar system elsewhere.

The key to this approach is a reliable sensing, decision-making and information dissemination system. Significant Code changes would be required implement these options.

11. Overcrowding of Elevators

One of the concerns that need to be addressed is the issue of overcrowding of elevators in an emergency. The concern is that the load weighing system will prevent the elevators from moving or the elevator will slip traction or overcome the brake. The elevator could accelerate in an uncontrolled manner, until the governor trips the safety, thus entrapping passengers in the elevator.

A study of the area for a given load required by the major elevator codes indicates that it is very rare that an elevator is overloaded. Experience bears this out under typical conditions. The A17.1 Code requires that elevators be capable of maintaining traction and brake function up to 125% of rated load, although rated performance is not required. It is, therefore, conceivable that under emergency operation the elevators could run with degraded performance, i.e. reduced jerk, acceleration, and velocity at loads greater than the rated load. Door function using nudging, which over-rides the door re-opening devices, albeit at reduced speed could ensure that the doors are closed. Moreover, audible voice messaging could warn people to stand clear and keep them informed as to when the next elevator will arrive to rescue them. Again, significant Code changes would be required implement these options.

12. Concluding Remarks

Objective scrutiny of the assault on the WTC Towers on September 11, 2001, provides valuable guidance on approaches to the role of elevators in emergencies. Moreover, it highlights the urgency for developing practical solutions to this complex problem. The current philosophy for operating elevators during an emergency does not exploit their potential as a major contributor to the evacuation process. Moreover, due to lack of confidence, they are not being utilized in many jurisdictions to the extent envisaged by the elevator and other Codes. This urgent issue has global visibility and is being studied at the ISO level, where a comprehensive Risk Assessment has been commenced. The results of this are intended to provide guidance to Codes and Standards development bodies. In parallel with this initiative, studies are underway to examine how building and elevator systems information may be used during an emergency to establish whether a given elevator is safe for use. By providing in-car, real-time monitoring of essential systems, emergency personnel would establish that the elevators are safe to use for firefighting and rescue operation. Use of some of the elevators by building occupants, preferably under the supervision of a trained "Floor Captain" could be permitted subject to a real-time audit of the safety aspects, this could be automatically performed based on elevator and building system condition information. Some of the normal "safety-chain" functions could be bypassed to allow the use of the elevators with degraded performance under initial overload conditions. The use of reinforced building and distributed building cores could enhance the resistance of buildings to emergencies and house the elevators in a more protected environment. Elevators which are hardened to resist water and smoke and which are powered by redundant power supply systems could be operational during emergencies.

The World Trade Center tragedy has focused attention on the issue of building evacuation in an emergency condition. It is clear that many opportunities exist to enhance the role of elevators in such situations. It is imperative that the building industry address the issue in unison, and that Codes and Standards developing bodies, as well as first responders are aligned in the process. Concerted action will lead to a major improvement in safety on a global scale.

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