Elevators for Emergency Evacuation and Egress

Roger E Howkins

Ove Arup International Ltd, Research & Development
13 Fitzroy Street, London. W1T 4BQ UK

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ABSTRACT

Codes on a world-wide basis require new buildings, architects, developers and owners to provide provision for means of access to the building for citizens who have a disability, yet make no provision for the safe, rapid egress in an emergency evacuation, especially during fire conditions. Codes today consider that the passenger elevator to be incapable to fulfil this function, yet enlightened codes such as *British Standard BS 5588 part 5* allow the fire-fighters to use an elevator which is designed to assist the fire-fighters to fight the fire.

This paper will ask the questions, why cannot elevator systems in the "next generation" of building if correctly designed and risk assessment procedures are implemented, installed, commissioned and maintained should not be used for safe, emergency egress and evacuation?

Also why are traditional methods of emergency egress considered safer when the potential hazards encountered during emergency evacuation conditions are greater?

1. DISCUSSION

Building codes whether they are Local, Regional or National make provision for access for the disabled such as ADA (Americans Disability Act -USA), DDA (Disability Discrimination Act – Australia) or M2 (The Building Regulations – UK) all of which require in general terms that citizens with a disability are treated equally in terms building access and personal facilities within the building. Which generally require that the elevator systems are provided with various devices such as tactile buttons, computer generated voice announcements, colour co-ordinated finishes and control devices set at certain locations and heights for the ease of the disabled and also the able-bodied or what is generally as classified as "universal access".

However, universal access becomes a prison to the citizen with a disability when an emergency condition occurs within a building, and a populated floor has to evacuated, the able bodied should be capable of using the stairways, or are they?

Codes make provision for generally access but generally do not consider emergency egress for those with a disability.

Statistics have shown that 19% of citizens have a disability, this percentage has increased by 1-2% since 1993 due to the ageing population, this will have an effect on the overall new building design population. If the building is designed for a high proportion of elderly citizens in the age range 60-69 years the proportion of those with a disability will increase to 40%. These high percentages of citizens with a disability will also affect the elevator system handling capacities but more importantly for those citizens with a disability it will cause additional hazards during an emergency condition, as it will create additional "bottle-necks" and "pinch-points" at designated emergency exits due to their lack of mobility.

The next generation of building which will range from the multi storied high-rise tower to the low–rise developments, the population massing on each floor plate will be as high as possible high to enable the building developer the fastest return on their investment. Although this floor massing will vary in each City or Country and will range from 1 person 6m² for a dealer floor to 1 person 14m² for a generally office building, of which on average 19% of the population will have a disability.

Technically it could be argued that the building developer has a "duty of care" not only to provide safe ingress but also safe egress to the building under all conditions including emergencies, but do they?

2. THE ELEVATOR SYSTEM

When considering emergency evacuation by elevators in the next generation of building, the designer must consider the effects of overall safe population movement and how the flow can be monitored. Today elevator system designers consider how to move a percentage of the building population vertically up the building during a theoretical "up peak" period with a defined average waiting interval. A building design brief may require that the elevator system is required to move 17% of the designed building population within a 5 minute period with an average waiting interval not exceeding 30 seconds, elevator systems that cannot meet these basic criteria could be described as poor which will possibly have a negative marketing effect of the building and could reduce the marketable value of the building. With rental values of new high quality buildings e.g. in London exceeding £50.00ft², it is vital to have the correct general elevator system during the up-peak conditions and also for day to day vertical movement.

In the next generation of building, the general elevator system will also be required to assist in the phased evacuation of the building during an emergency condition, therefore the elevator designers will be required to model various scenarios to prove that the building is safe. These scenarios will include using the elevators to evacuate the building population from possible hazardous areas such as fire floors, above and below the fire-fighters bridgehead floors to "safe havens" within the building.

These safe havens do not have to be outside the building and also very importantly they do not require the general evacuation of the total building but only evacuation from those levels considered at risk. With powerful elevator simulation programs such as *Elevate* it is now possible to model passenger movement and queuing lengths within elevator lobbies and with Fire Engineering programs such as *Simulex* which simulates how able-bodied people will react and move around a floor plate if a fire starts in a defined location.

These powerful design tools and will form a vital part of any risk assessment, which must be carried out to evaluate the evacuation procedures within the next generation of building.

3. ELEVATORS OR STAIRS

From published accident statistics (refer to Section 6) the use of a stairways is a relatively dangerous activity during normal building use, within any building using stairways during an emergency could be considered negligent due to the inherent high risk of accidents and personal injury caused to the individual and also subsequently inflicted on others.

Designers should consider the following design scenarios:

- Time required to evacuate the primary floor to a safe haven.
- Time required to evacuate the primary and secondary floors to safe havens.
- Time required to evacuate the primary floor to the main lobby.
- Time required to evacuate the primary and secondary floors to the main lobby.

From studies carried out on tall buildings (buildings between 40 – 45 floors), it was considered that "when people are evacuating by stairs they are exposed to dangers" which were defined as "tiredness, becoming dizzy, slipping on surfaces or be less capable physically" and that "a stair evacuation will also take an unreasonable long time to carryout".

During these studies it was timed that persons of high fitness levels took approximately 12 minutes to walk down to the ground floor using a firefighting stairway in a 42 storey building.

The studies also concluded that a person able bodied or those with a disability "once inside the elevator, in an elevator evacuation control mode will be on the ground floor in approximately one minute" the 11 minutes additional risk by using the stairway was considered to be unacceptable.

4. RISK ASSESSMENT

For the elevator system is to be used for emergency evacuation in the next generation of building it will be required to carry out a detailed risk assessments of the evacuation procedures being considered.

As a starting point the elevator system designer will be asked, why is the elevator is safer than conventional evacuation methods i.e. stairways?

Or to ask the question differently, if by detailed risk assessment procedures the elevator systems can be proved to be safer than the stairway during an emergency condition why should they not be used?

The recognised basic norm of carrying out a risk assessment is to classify two critical factors:

- Probability & Severity.

These two factors are weighted to provide an overall Risk Category, from which the hazard rating can be determined and control measures put into place.

The hazard rating is based on multiplying the probability and severity assessments, which give the over-all risk category.

The risk assessment matrix is detailed in Table 1.

<table>
<tr><th colspan="2">Probability</th><th colspan="2">Severity</th></tr>
<tr><td colspan="2">Impossible x 1
Possible x 2
Probable x 3
Certain or near Certain x 4</td><td colspan="2">Negligible x 1
Serious Injury x 2
Critical x 3
Catastrophic x 4</td></tr>
<tr><td colspan="4">Risk Category</td></tr>
<tr><td>Low = 1–3</td><td colspan="2">Medium = 4-8</td><td>High = 9-16</td></tr>
</table>

Table 1. Risk Assessment Matrix

See Table 2 for example of risk assessment.

Hazard: A buildings elevator system which is in a potential high risk location from vandalism or other anti social activities, what is the risk to the occupiers from broken glass?
Probability: category 3 (probable) Severity: category 2 (serious injury)
Hazard Rating: probability (3) x severity (2) = (6) Medium
Control measures: Use laminated, toughened glass or use protective film on glass.

Table 2. Risk Assessment - Example

5. INJURY STATISTICS

Prior to considering the risk assessment procedures that need to be undertaken so that the elevator systems are to be used for emergency evacuation, relevant accident statistics relating to employees e.g. in office based industries need to evaluated.

In the UK in the period 1998/99 there were approximately 223,000 office based premises employing approximately 3.8 million people.

During the 5 year period 1994/95 to 1998/99 in the UK, there were 8,343 reported injuries in the office based industries, of these 13 were fatal and 6,319 resulted in the employee being off work more that 3 days, 27% (1,681) of these injuries resulted from a slip or trip, of which 309 were attributed to slipping on stairs.

Of the 704 injuries attributed to falls, 387 involved a fall down stairs.

The 6,319 injuries sustained 40% were sprains or strains or which 696 could be linked directly to stairways, during the 5 year investigation period only 5 injuries could be attributable to fire.

These published statistics are very significant they indicate that using the stairway during normal building occupation is potentially a very hazardous activity, should this common everyday activity be attempted during an emergency condition where there could be mass population evacuation, slippery stair tread causing a minor slip or fall could have a "domino effect" causing not only possible serious injury, but probably fatalities caused by crushing, broken limbs and cardiac conditions.

6. EVALUATIONS

With any new concept there are justifiable fears and concerns which must be addressed and fears and prejudice overcome by scientific argument, and risk assessment procedures, and the doubters must come to discussions with an open mind and not "with their eyes wide shut" and importantly not with the Towering Inferno Syndrome (T.I.S.) conceptions.

T.I.S. is a journalistic headline grabbing statement, where new or inventive designs are quickly misjudged and the headline writers zero in on the publics fears and generic concerns on tall buildings based upon the disaster movie of the same name. What the journalists fail to highlight were the poor working practices, corruption and a total disregard for building codes and practices which were the underlying theme of the movie.

There have been instances of first generation tall buildings where fires have resulted in loss of life, a review of these fires, came up with the following Design Based Conclusions:

- Partial or no automatic sprinkler system
- No fire detection or alarm systems
- Lack of enclosed, fire rated stairways
- Flammable wall & ceiling linings
- Inadequate compartmentation between floors

It must be emphasised that these fires occurred within first generation buildings, the next or 4^{th} generation of building will be provided with all the safety features which were not installed or operational within the buildings where serious fires occurred.

With the next generation of building, the perceived risks to people during evacuation by elevator can be described as:

- Reliability
- Smoke
- Fire
- Water
- Radiation
- Power Supply

Although perceived concerns are valid they must be taken in the right context and relate to the safe evacuation and should also include traditional methods of evacuation by stairways, therefore the Risk Assessment methods should be re-defined, refer to Table 3.

	Elevators	**Stairways**
Risk	Probability Severity	Probability Severity
Reliability		
Effects of Smoke		
Effects of Fire		
Effects of Water		
Effects of Radiation		
Power Supply		

Table 3. Risk Assessment Comparison

Risk Assessment procedures cannot give a defined statement, without considering the cause/effect and what design changes will need to be undertaken to achieve a risk assessment for all areas of perceived risks.

7. RELIABILTY

British Standard BS 5588 Part 5 Fire precautions in the design, construction and use of buildings: Part 5: 1991: Code of Practice for firefighting stairs and lifts, describes a standard design of elevator which is classified as a Firefighting lift, which is designed to be used by fire-fighters to assist them in fighting a fire. This elevator therefore is must operate in hazardous conditions such as fire, smoke, water and the by-products of a fire such as soot's and fumes etc.

This elevator must operate first time every time, if this design of elevator can be used as a design platform for the evacuation elevator, emergency evacuation by elevator becomes more than a concept it becomes a design reality.

A correctly designed, installed and maintained elevator on average will only require breakdown assistance no more than 4 times each year, (although this can reduce to less than 1.5 per annum or increase to more than 5 in countries where the maintenance procedures require adapting) these world-wide breakdown averages are based upon elevator companies overall maintenance portfolio, which will range from simple elevators with manual doors and relay logic technology to the highly sophisticated computer based systems.

The newer the elevator stock the greater the overall reliability providing the systems have also been designed, installed, commissioned and maintained correctly.

Although the duty cycle of an elevator system will alter from building to building, it can be assumed that a single passenger elevator in a group system within a commercial building will be required to operate on average for:

- 50 weeks every year, assuming a 5 day week.
- 9 hours each day.
- 75 movements each hour.

From these operational assumptions an average elevator in a group system will be required to work each year for:

- 250(days) x 9 (hours) x 75 (movements) = 168,750 elevator movements each year.

Statistics indicate that an elevator will require call back assistance only once every 42,188 movements or approximately every 62.5 working days. This risk is considered acceptable for a firefighting lift as defined by *BS 5588: Part5: 1991* and therefore should be recommended as the minimum design platform emergency evacuation.

Risk assessments should be carried our on the suitability of using stairways or elevators in normal and emergency operating conditions, examples are shown in tables 4, 5, 6 & 7.

Risk Assessment: Elevator Reliability - Normal Use
Hazard: Statistical breakdown trapping persons in elevator. Probability: 1 breakdown every 62.5 working days (risk category 2) Severity: Negligible no injuries (risk category 1)
Rating: 2 x 1 = 2 (Overall Risk Category = Low)
Control Measures: None required.

Table 4. Risk Assessment: Elevator Reliability – Normal Use

Risk Assessment: Elevator Reliability - Evacuation Condition
Hazard: Statistical breakdown trapping persons in elevator Probability: 1 breakdown every 62.5 working days (risk category 2) Severity: Negligible no injuries (risk category 1)
Rating: 2 x 1 = 2 (Overall Risk Category = Low)
Control Measures: In the statistically unlikely event of a elevator breakdown during an emergency, provide addition elevators and a safe method of escape from stalled elevator.

Table 5. Risk Assessment: Elevator Reliability – Evacuation Condition

Risk Assessment: Stairway Safety – Normal Use
Hazard: Injury to persons using stairs Probability: Possible (risk category 2) Severity: Serious Injury (risk category 2)
Rating: 2 x 2 = 4 (Overall Risk Category = Medium)
Control Measures: Recommend that vertical movement is only by elevator.

Table 6. Risk Assessment: Stairway Safety – Normal Use

Risk Assessment: Stairway Safety – Evacuation Condition
Hazard: Injury to persons in crowded stairway conditions. Probability: Certain or Near Certain (risk category 4) Severity: Critical (risk category 3)
Rating: 4 x 3 = 12 (Overall Risk Category + High)
Control Measures: Only allow emergency evacuation by the elevator system as the Risk category for elevators is classified as Low.

Table 7. Risk Assessment: Stairway Safety – Evacuation Condition

By carrying out a risk assessment on all possible areas of design concern by assessing the g1 elevator system against traditional means of evacuation, correctly designed elevator systems can be used for emergency evacuation which is safe, reliable and rapid.

The elevator designer must consider at a minimum the following factors and carry out detailed risk assessments for the stairways and elevator systems on the following areas of design:

- Smoke Control
- Effects of Fire
- Effects of Water
- Effects of Radiation
- Reliability of Electrical Power Supply

With key areas of design, requiring detailed risk assessment analysis it will enable the elevator design platform to proceed through the design development process, prior to incorporation into a new project design.

8. SMOKE

A risk assessment analysis will be needed to be undertaken on smoke control measures, comparing the effects of smoke possibly entering the stairways, lobbies and elevator systems, these risk assessments should consider but not be limited to:

- Pressurisation of elevator shafts, lobbies & stairways.
- Stack & Piston effects within elevator shafts & stairways.
- Design of Elevator lobbies and stairways
- Ventilation of elevator lobbies and stairways.

9. FIRE

Statistics show that fire alone is not the cause of fatal injuries, the effects of combustion are the hazard areas, which can include smoke and radiated heat. The elevator designer must carry out a risk assessment on the effects of a fire rather than the fire itself.

How will the areas of hazard possibly effect safe reliable evacuation operation of the elevator system or stairwell?

10. WATER

As a design issue water is not considered to be a major concern for elevators to be used for emergency evacuation, there are many location where elevators work reliably and in complete safety in fully external environments and in certain buildings these elevators are also classified as firefighting elevators as defined by *BS 5588: Part 5. 1991*.

The risk analysis must consider the potential effects of water on the elevator system stairways, but also should consider:

- Location of elevator machine space
- Drainage within shafts and stairways
- Location of sprinkler systems
- Design and specification of electrical systems.

11. RADIATION

With any fire high temperatures are generated from the combustible source, this radiated heat requires control if it is not to effect people, buildings and life safety systems equipment, if people are in an elevator or stairway, an unprotected or insulated surface, e.g. which has a temperature of 100°C will cause a significant injury if a person touches the unprotected surface for risk assessment the following design issues will need to be considered:

- Effects on elevator methods of suspension
- Effects on elevator control wiring and control sub-systems
- Effects on surface temperature
- Effects on materials and fixing methods

12. POWER SUPPLY

A stable and reliable power supply is not only required to operate the elevator during normal and emergency conditions but it is also required to stairways in the form of general lighting, announcing systems or power to the pressurisation fans. The risk analysis will need to consider:

- Protection of power supply
- Primary and Secondary supplies
- Duration of secondary power supplies

13. CONCLUSIONS

Controlled emergency evacuation within the next generation of building by elevators, is a global issue not only for the able bodied but also for the 19% of the working population who have or will have a disability.

By use of detailed risk assessment procedures the modern elevator system can be designed to provide safe egress from buildings during emergencies. Design work currently being undertaken includes fault and event trees, occupant behaviour and effects on architectural design.

The occupants of the next generation of building will demand the safe evacuation procedure to be only by the intrinsically safe and reliable elevator system, which have been designed, installed, commissioned for emergency evacuation.

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ABOUT THE AUTHOR

Roger E Howkins is an Associate with Ove Arup International Ltd – Research & Development in London and is the leader of their vertical transportation team providing advice and assistance to Arup and private clients on a world-wide basis. He an advocate of the use of the use of elevators in fire conditions and also an authority on Panoramic Elevator design solutions and the systematic method of elevator modernisation and has an active interest in providing "universal access and egress" to building for people with a disability. Roger E Howkins has written a book on Lift Modernisation with a set of visual aids, he has also present technical papers on various aspects of elevator technology World-wide and is a regular contributor to Elevator World. Roger E Howkins is a Companion member of the Chartered Institute of Building Services Engineers (CIBSE) and sits on various National and International Code Committees.