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Guidance on the emergency use of lifts or escalators for evacuation and fire and rescue service operations

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The findings and recommendations in this report are those of the authors and do not necessarily represent the views of the Department for Communities and Local Government.

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Contents

Chapter 1

Scope

This document provides guidance on the emergency use of lifts or escalators for evacuation and fire and rescue service operations. It provides guidance on the factors that should be considered by building designers, approvers and building operators and managers. There is guidance on the process to be adopted when considering the adoption of lifts or escalators for emergency evacuation. The guidance also addresses their use in both new and existing buildings and for fire and certain non-fire incidents, such as Imminent Catastrophic Events (ICE). ICEs are where there is some warning of a significant non-fire threat to a building.

A wide range of building types may benefit from the use of lifts and/or escalators for emergency evacuation of the general population, from high-rise offices to underground stations and airports. The factors that may affect the emergency use of lifts and/or escalators for evacuation are many and varied. Therefore, it is inappropriate to provide detailed prescriptive guidance. However, this guidance provides information on the potential benefits of using lifts or escalators for emergency evacuation and a process for addressing the issues that should be considered.

The guidance considers the implications and opportunities to improve safety in the light of the evacuation of the World Trade Center in 2001. Therefore, this guidance is intended to improve safety by increasing redundancy and diversity in the vertical means of escape. This objective is reflected in Section 3.3.1 in the guidance on escape stair width provision and in the guidance on acceptance criteria in Section 4.3.5.

For new buildings, the provisions in this guidance are additional to those in the Approved Document to Part B of the Building Regulations [10]. For existing buildings, no guidance in this document should be used to reduce the level of fire safety.

Chapter 2

Background

For any multi-storey building, lifts, escalators and accommodation stairs provide a possible means for increasing total evacuation flows and reducing clearance times in various emergency situations. Advantages of using these as means of escape are that building occupants are likely to be familiar with them, and to have used them as their means of entry or for general circulation around a building.

Accommodation lifts and, to a lesser extent, escalators also provide a useful means of evacuation for mobility impaired or non-ambulant occupants. The main differences between these and the evacuation stairs is that they are not 'passive' components, so they may require active control and there is more potential for their operation to be affected during an incident. The extent of enclosure and passive fire protection may also not be to the same standard as emergency stairs [10] or evacuation lifts [3].

The rationale for using escalators and lifts as part of an emergency evacuation strategy therefore depends upon a number of aspects including the building type and design, the technical specification and protection of the escalator/lifts, the characteristics of the occupants, the fire safety management strategy and the types of emergency scenario under consideration.

A particular category of buildings for which lifts have been successfully incorporated into a (non-fire) simultaneous evacuation strategy is high-rise buildings designed for phased evacuation during fires. This is the case for a number of tall office buildings, for example, on the Canary Wharf site in London, where use of both lifts and emergency stairs in simultaneous evacuation exercises has reduced total evacuation times to between 6 and 28 minutes (depending upon the size and occupancy levels of the buildings), representing a decrease in evacuation time of up to around 50% compared to that obtained using emergency stairs only [1].

In the investigation into the World Trade Center (WTC) [2] collapse it was found that in the 16 minutes before the impact of the second aircraft, 27% of those who evacuated WTC2 used the elevators [lifts] for part of their escape route. In addition, the investigation found some evidence that the flow rate from WTC2 during these 16 minutes was approximately twice that for WTC1 (where only stairs were available for evacuation).

There is some evidence from the collapse of the WTC towers that stair flow rates were approximately 50% of those measured during evacuation drills. This may have been partly because the stairs were not used to full capacity. However, potential difficulties during the evacuation of the WTC towers included obstructions, mobility impairment, illness, fatigue, counter-flow and footwear.

Approximately 1,000 surviving occupants of the WTC (out of 9,000) had a limitation that impacted their ability to evacuate, including recent surgery or injury, obesity, heart condition, asthma, advanced age and pregnancy. The most frequently reported disabilities were recent injuries and chronic illnesses.

2.1 Introduction to lifts, escalators and escape stairs

2.1.1 Lifts

Lifts are a well-known means of transporting people vertically between the floors of a building. Their outward appearance could be considered to be simple; the push of a call button eventually resulting in the arrival of a lift, and subsequent selection of a destination leading to eventual arrival at that destination. Their design is, however, tailored to the building in which they are situated, and has evolved over a number of years as a result of pressures to reduce the amount of space required by lift systems, to increase levels of safety, and to reduce the cost of their installation and use.

Lifts can be characterised as particularly effective where there is a large change in height or a batch flow process. Key performance measures are the quantity of service and quality of service. Protection may be required to prevent smoke ingress into the lift car and/or shaft and assist the extrication of occupants from a lift car stuck between floors.

2.1.1.1 Lift performance

Lifts are characterised by their load capacity and speed of operation (which is determined by both their maximum acceleration and speed). These factors influence the quantity of service which a lift can provide, though the control system managing how the lift responds to calls from the call points will also have an effect.

The load capacity of a lift is often given in two forms. The maximum mass of the load being transported is reasonably straightforward. From this maximum mass the load capacity tends also to be expressed as the number of people which that lift can accommodate. It should, however, be noted that the maximum number of people is determined using the assumption that each person weighs 75 kg. In practice, the number of people that will use a lift is dependant upon the floor area of the lift and the willingness of individuals to enter the lift as it becomes progressively more crowded.

The speed of operation of a lift is dependant on the maximum speed at which a lift can travel, how quickly a lift can accelerate to that speed, and how quickly it can decelerate at its destination. The speed of acceleration is limited by the need for the lift to provide a comfortable environment for its passengers.

Lift management systems determine how efficiently a lift or set of lifts make use of their load capacity and speed of operation to transport passengers. The management system will decide how the lift reacts to calls at the levels serviced by the lift and the calls made by the passengers within the lift. These management systems can be customised to suit the occupancy of a building and how its use may change during the course of the day.

The design of a lift system is based upon two factors: the anticipated quantity of service that will be required, and the intended quality of service that will be provided.

2.1.1.2 Quantity of service

Quantity of service (particularly in the case of new builds) can be determined via assessment of the occupancy of a building, in terms of both population density and the nature of the occupancy (commercial, domestic, office, etc). This assessment will lead to an expected passenger frequency expressed as the number of passengers per 5 minutes. Depending on the type of occupancy, as described earlier, passenger frequency will be taken as either the average during the course of an entire day, or the average during the periods of peak traffic through the building (such as beginning and/or end of the working day in an office). Existing buildings have the obvious advantage of being able to provide measured data upon which designs can be based, but the lower frequency with which these tend to be subject to renovation or present scenarios that can be applied to other new builds mean that many designers are forced to make decisions based on anticipated usage rather than known usage.

2.1.1.3 Quality of service

Quality of service can be determined in a number of ways but generally deals with the amount of time that passengers will spend during, or have to wait for a particular part of, a journey using a lift. For example, quality of service can be determined from the amount of time that a passenger must wait between pressing the call button for a lift and the arrival of the lift. With respect to design, the quality of service that a lift will provide could be considered to be the compromise that is made between the need to deal with passengers as quickly and efficiently as possible, and the need to limit the amount of resources that are fed into the design and use of the lift system.

It is common knowledge, as often indicated on signs located in and around lifts, that conventional lifts are not to be used in the case of emergency. BS EN 81-73:2005 [12] currently stipulates the actions to be carried out by a non-fire-fighting lift in the event of a fire. These actions are designed to bring that lift to the designated lobby as quickly as possible and to immobilise it there. This is to avoid passengers becoming trapped in a lift during a fire, to allow the fire and rescue service to quickly confirm that lifts are unoccupied (achieved through their inspection at the designated lobby), and to avoid passengers being exposed to heat and smoke by using the lift during a fire.

Further details of the performance of lift systems can be obtained from CIBSE Guide D: *Transportation systems in buildings* [13].

2.1.2 Escalators

Escalators provide a mechanical means of continuously transporting pedestrians from one level to another. They are typically provided for travel between levels only a small number of storeys apart. Escalators can normally be found in many types of building, including offices, shopping centres, stations, hospitals and museums. Their handling capacity depends on a wide range of characteristics, including: speed, step width, inclination and size of boarding and alighting areas (see CIBSE Guide D [13]).

Escalator speed is measured in the direction of the movement of the steps. The most common speed is 0.5 m/s, but 0.65 m/s and 0.75 m/s speeds are also available. Most escalators are constant speed, although some heavy duty escalators can increase their speed at times of high demand. London Underground uses a speed of 0.75 m/s, and other metro systems in Russia and Ukraine use up to 0.9 – 1.0 m/s in deep systems.

Step widths of 600 mm, 800 mm and 1000 mm are available with the latter allowing two columns of people to be carried. The usable width at hip level is typically 200 mm wider than the step width. So a 1000 mm step width provides a 1200 mm width at hip level, which is sufficient for two people to pass each other.

Most escalators are inclined at 30°, although the inclination can be as high as 35° with a maximum speed of 0.5 m/s and a maximum rise of 6 m. Specialist escalators in transport interchanges and stations can have rises of 20 m or more. The step tread (going) is 400 mm and the step rise is then fixed by the inclination. This usually gives a stride much longer than a normal walking stride, which is why escalators are much harder to walk up than stairs.

At 0.5 m/s, it takes less than 0.8 s for a new step to appear. Therefore, BS EN 115: 1995 [14] recommends that at least two to four flat steps (depending on the duty of the escalator) be provided at the start and end of the escalator. Definitions of duty are provided in BS 5656-2: 2004 [15]. For example, a 1000 mm escalator moving at 0.5 m/s has a handling capacity of 150 people per minute.

Escalators are recommended for bulk transit systems because of their high handling capacity and continuous nature. Lifts, by comparison, typically have a much lower handling capacity and have a considerable 'throttling' effect on pedestrian movement.

In summary, escalators can be characterised as particularly effective for high flow rates and across a small number of storeys. They enable a continuous flow process. Protection may be required for maintaining compartmentation and preventing and protecting against crush incidents at the end of the escalator.

2.1.3 Escape stairs

By way of comparison with lifts and escalators, escape stairs can be characterised as:

- continuous
- high capacity
- simple and robust
- relatively low flow rate compared to escalators
- not as inclusive as lifts for occupants whose mobility is impaired.

Protection may be required against slips, trips, falls and fatigue by incorporation of details such as emergency lighting and resting areas, and variation in stair design.

2.1.4 Current practice in the use of lifts and escalators for emergency evacuation and fire-fighting operations

In existing buildings, lifts and escalators already form part of the means of escape and fire and rescue service operations in certain circumstances, for example, for:

- occupants with disabilities [3]
- certain high-rise offices [4]
- underground stations [5]
- some hospitals [6]
- some communications/air traffic control towers
- fire and rescue service access [7].

Annex A summarises some current practice in the emergency use of lifts for evacuation and fire and rescue service operations.

Chapter 3

General considerations for the wider use of lifts or escalators for emergency evacuation

The application of escalators or lifts to an evacuation strategy depends upon a number of considerations:

Some of the benefits of using lifts and escalators for emergency evacuation rather than stairs include:

- for the evacuation of some elderly/disabled occupants, lifts may be the only option
- occupants typically exit the same way they entered and therefore are utilising familiar routes
- less physical effort is expended
- stair congestion is reduced
- evacuation time is decreased.

There are, however, also potential issues that should be resolved before lifts and escalators can be more widely adopted for emergency evacuation, including:

- current practice and training not to use general lifts or escalators for escape from fire
- consistency of approach between buildings
- extent of passive protection and compartmentation
- potential exposure to fire gases or other harmful substances whilst waiting for a lift
- lift and escalator availability, reliability and failure modes
- human factors, such as exit choice behaviour.

There are also counter concerns about the tenability of current evacuation practices such as phased evacuation (that is when the fire floor and then the adjacent floors start to be evacuated before other floors progressively start evacuation) of high-rise buildings. For example, if people on floors other than the incident floor are aware of a fire below, will they continue to wait until an evacuation alarm sounds on that floor?

Lifts and escalators can be used to reduce the simultaneous evacuation time (ie all people starting to evacuate at the same time) for many multi-storey buildings, but primary considerations relate to the basic building design, occupancy type and emergency management strategy. The following sections discuss general considerations with respect to different categories of building. In all buildings with lifts, it is worth considering the potential benefits of their use for emergency evacuation for people with disabilities.

3.1 Factors that may affect the benefits and ease of implementation of lifts and/or escalators for evacuation

Table 1 shows a summary of the factors that may affect the benefits and ease of implementation of lifts and/or escalators for evacuation.

Table 1 Summary of factors that can affect the benefits and ease of implementation

Aspect	Factor	Evacuation using lifts and escalators likely to be more beneficial	Evacuation using lifts and escalators likely to be less difficult to implement	Comments
Occupants	With mobility impairment	√	√	Applies to all buildings. Lifts for emergency evacuation may increase the degree of inclusive design
	High number of occupants	√		For example, high-rise office or underground station
	Familiar with the building	√	√	Occupants can also be familiar with a 'non-standard' evacuation strategy
	Awake	√	√	Lower pre-movement times and more able to consider alternative escape modes
	Trained	√	√	Can be trained in a 'non-standard' evacuation strategy
Building	High-rise	√		High populations with limited means of escape

Table 1 Summary of factors that can affect the benefits and ease of implementation *continued*

Aspect	Factor	Evacuation using lifts and escalators likely to be more beneficial	Evacuation using lifts and escalators likely to be less difficult to implement	Comments
	Underground	√		Occupants needing to escape upwards. Escalators best for large numbers of people at relatively shallow depths and lifts for deeper underground
	Target for terrorism	√		Increased likelihood of an ICE
	Phased evacuation	√		Escape stairs not designed to provide fast simultaneous evacuation
	New		√	Systems for evacuation using lifts and escalators can be considered at the design stage
	Modern lifts		√	Collective modern lifts can be programmed to have an evacuation mode
	More than one smoke zone or compartment on each level		√	Protection to lifts and escalators in adjacent smoke zones or compartments, eg airports, shopping centres and hospitals
	Single tenant		√	Ease of coordination and evacuation management
	Simple layout		√	Low egress complexity means ease of switching modes
Event	ICE		√	Imminent Catastrophic Event – so evacuation before hazard present
	Fire			Concerns about robustness in an escalating fire event

3.2 Low-rise multi-storey buildings and underground complexes designed for simultaneous means of escape

3.2.1 Existing buildings with an unprotected escalator or accommodation lift

Low-rise multi-storey buildings are usually designed for simultaneous means of escape. Depending upon their height they are likely to have protected emergency stairs, but escalators and lifts often open directly onto occupied floors. Such designs are typical of retail stores, which often have open voids within the building over several floors.

Lifts, and especially escalators, provide a means of obtaining a more efficient and rapid evacuation than sole use of the protected emergency stairs, especially when a building is crowded. When considering whether it is advisable to use them in such a building, consideration should be given to the envisaged emergency scenarios and the quality of the fire safety management [7].

3.2.1.1 Trained staff

For most potential fire scenarios, there would be a period of up to several minutes before open escalators and lifts may be exposed to fire effluent. Other emergency evacuation scenarios, such as an Imminent Catastrophic Event (ICE), may not involve contamination of building interior spaces. If sufficient well-trained staff are present and in control of the lift or escalator it may be feasible to allow their use until conditions deteriorate (eg smoke in the lift shaft) to the extent that their use becomes unadvisable. This consideration might also extend to other emergencies requiring rapid simultaneous evacuation.

If sufficient well-trained staff are unlikely to be available it is probably unadvisable to use unprotected lifts and escalators as part of an emergency evacuation plan, since it is possible to envisage a number of fire scenarios or other emergency scenarios in which their use may become hazardous after a few minutes. In two major hotel fires in the United States (MGM Grand and Dupont Plaza), occupants died when lifts descended to the fire floor and opened onto unprotected areas involved in the fires. Other occupants had escaped previously by using the lifts.

3.2.1.2 Behavioural scenarios

An important consideration is the Design Behavioural Scenario (see PD 7974 Part 6 [8]). In scenarios where occupants are likely to be awake and familiar with the building (such as in an office building), or awake and unfamiliar (such as in a retail store), and with Level 1 fire safety management [7], most occupants can be expected to begin a simultaneous evacuation within one or two minutes of an alarm. For a low-rise building with a high population density, emergency escape routes can rapidly reach flow capacity, but total building evacuation times can be significantly shortened by the use of escalators and lifts at the same time as stairs.

For an 'asleep and unfamiliar' behavioural scenario, such as in a hotel, pre-movement times can be very long (up to approximately an hour). This means that emergency escape stairs do not reach flow capacity, so that the use of lifts or escalators does not necessarily result in a more rapid evacuation. Also, occupants attempting to leave via unprotected escalators or lifts at a late stage of an incident are more likely to encounter life-threatening conditions.

3.2.2 Protected escalator or accommodation lift

Many buildings designed for simultaneous evacuation will have protected stairs with a protected fire-fighting or evacuation lift [3][4]. These are suitable for the evacuation of small numbers of occupants who may find stair use difficult.

In some buildings the escalator or accommodation lifts may be in a fire-protected compartment. In such situations their incorporation into a fire or ICE evacuation strategy becomes a more feasible proposition. Consideration will still need to be given to the methods of control and vulnerabilities of lifts and escalators, and how their use will be managed. For example, lifts and their shafts may be vulnerable to smoke ingress in a fire situation.

As described in Annex B, the benefits in terms of reduced evacuation times are somewhat less for buildings designed for simultaneous escape, since they tend to be of limited height and have an increased emergency stair capacity compared to buildings designed for phased evacuation. However, in situations when it is advisable to move large numbers of occupants rapidly away from a threatened area (for example, in large low-rise retail stores, underground stations or airports), then escalators and protected accommodation lifts can have a useful place in an evacuation strategy.

3.3 High-rise buildings designed for phased evacuation

High-rise buildings designed for phased evacuation are mostly office buildings. Typically, each floor is a fire compartment and emergency stairs, lifts and escalators are also compartmented. The standard fire strategy is to plan for evacuation of the fire floor first, via the stairs, followed by other floors later, if required, so design stair width and capacity are limited compared with those in buildings designed for simultaneous evacuation. This means that stairs are likely to become highly congested during a simultaneous evacuation of more than a few floors, especially if the building occupancy level is close to the design maximum.

Since the lifts and escalators are protected, they provide a means to expedite a simultaneous or sequential evacuation of a building if required. In both experimental and real emergency situations the combined use of lifts, escalators and emergency stairs has been shown to considerably increase total evacuation flow rates and reduce vertical evacuation movement times by up to around 30% (see Annex B).

In the Qualitative Design Review (QDR) which is carried out during the fire safety engineering design process (see BS 7974 [9]), consideration should be given to the degree of protection and operational capabilities of the lifts and escalators, and to control and management within the context of the overall fire safety and evacuation management strategy. Since the majority of occupants of such buildings are likely to be in the 'awake and familiar' category, they will be familiar with the building and systems, and trained in the building emergency procedures. In this case, the lifts and escalators can readily be incorporated into the emergency evacuation plan for an ICE.

3.3.1 Escape stair provision

The use of lifts solely for the general emergency evacuation from ICE events should have no effect on stair provision, as stairs would be the main means used in the event of a fire.

For emergency evacuation from fire events, it is considered that lifts are unlikely to present a realistic opportunity to reduce stair provision. Within the current version of Approved Document B (AD B) – Fire Safety 2006 [10], it is considered that a stair may have restricted access at some stage of a fire, so that lifts may help to maintain the minimum acceptable level of building evacuation flow capacity in some situations and in other situations, enhance it. Specifically, in paragraph 5.39 of Volume 2, AD B [10] states:

> "In general it is not appropriate to use lifts when there is a danger of people being trapped in a lift that has become immobilised as a result of a fire. However, in some circumstances a lift may be provided as part of a management plan for evacuating people. In such cases the lift installation may need to contain a number of safety features that are intended to ensure that the lift remains usable for evacuation purposes during the fire. Guidance on the design and use of evacuation lifts is given in BS 5588-8:1999.
>
> Where a fire-fighting lift has been provided to satisfy requirement B5, this can be utilised as part of a management plan for evacuating disabled people. Any such plan should include a contingency for when the fire and rescue service arrive."

The evacuation from the World Trade Center in 2001 indicated the potential benefits of using lifts for emergency evacuation. Their main benefits were to:

- increase simultaneous evacuation capacity (particularly in high-rise buildings designed for phased evacuation resulting in a low stair flow capacity relative to the population of the building)
- increase redundancy in the vertical evacuation provisions, should parts of it become compromised by a fire or extreme event, and
- increase diversity in the vertical evacuation provisions, should one type of evacuation provision become compromised or fail on demand.

Any reduction in stair provision below that in Approved Document B (AD B) – Fire Safety 2006 [10] would reduce and compromise these benefits, particularly in buildings designed for phased evacuation where stair provision is already relatively low.

Chapter 4

Design procedure for the consideration of lifts/escalators for emergency evacuation

If lifts and/or escalators are to be used for emergency evacuation in a new or existing building, this should be given full consideration by the fire safety team for the building. The fire safety team may consist of the following:

- building owner/operator
- lift/escalator engineer
- fire safety engineer
- architect
- building approval authority
- fire authority
- building services engineer
- structural engineer.

Depending on the nature of the building, there may also be a need for structural and building services engineers to form part of the fire safety team.

The fire safety team should use the Qualitative Design Review (QDR) procedures set out in BS 7974 [9] to assess the implications for the use of lifts/escalators for emergency evacuation in fire and/or ICE (Imminent Catastrophic Events) events. The following sub-sections identify some of the issues that should be considered during the QDR process.

The Qualitative Design Review (QDR) is a qualitative process that draws upon the experience and knowledge of the team members, and should be used to identify the inputs to the quantitative analysis and acceptance criteria for the building design.

The QDR is a technique that allows the team to think of the possible ways in which a fire hazard might arise and establish a range of strategies to maintain the risk at an acceptable level. The fire safety design can then be evaluated quantitatively against the objectives and criteria set by the team. The QDR should be conducted in a systematic way to ensure that no relevant item is omitted.

4.1 Personnel involved in conducting the Qualitative Design Review

For projects involving the emergency use of lifts or escalators for evacuation, the QDR should be carried out by a study team involving a fire safety engineer and the person(s) who will carry out the quantified analysis [which may be the same person(s)], a lift or escalator engineer and other members of the design team and a member of operational management. This ensures that all individual aspects of the design can be considered in the context of the fire safety objectives and that the impact of proposed solutions on other aspects of the design is fully appreciated. It may also be appropriate to include representatives of the approvals body in the QDR team.

For smaller projects, the QDR may be carried out by a smaller study group but the same basic review process should be followed. The make-up of the QDR team should be based on the nature and size of the project and on the extent of the analysis conducted. The QDR team should always include a fire safety engineer as well as other members of the design team, a lift or escalator engineer and a member of operational management.

4.2 Timing of the Qualitative Design Review

Ideally, the QDR should be carried out early in the design/review process so that any substantial findings can be incorporated into the design/refurbishment of the building before the working drawings are developed. However, in practice, the QDR process is likely to involve some iteration as the design process moves from broad concept to greater detail. The QDR process can equally be undertaken as part of a review of the fire precautions in an existing building.

4.3 Procedure for undertaking a QDR for vertical evacuation

The following steps should be taken when conducting a QDR for vertical evacuation:

a) Review of the building/design:
   i. Building characterisation
   ii. Building environs
   iii. Occupant characterisation
   iv. Management of fire safety

b) Establish fire safety objectives

c) Identify fire and/or ICE hazards

d) Identify additional fire/safety precautions

e) Identify acceptance criteria and methods of analysis

f) Establish evacuation scenarios for analysis

All findings should be clearly documented so that the underlying philosophy and assumptions that underpin the design can be clearly understood by a third party, eg an approvals body.

4.3.1 Review of the building design and/or operation

4.3.1.1 Building characterisation

In the first stage of the QDR the project should be described by reference to schematic drawings, models, etc or of the building itself, and any architectural or client requirements that may be significant in the development of a fire safety strategy should be highlighted.

All the relevant available information about the building, its use and its anticipated contents should be provided and reviewed.

The potential emergency use of lifts for evacuation in all buildings with lifts could be of benefit for people with disabilities. The layout and geometry of the building and details of the construction (eg high-rise, open plan etc) will have a significant influence on the potential benefit of lifts/escalators for emergency evacuation of other people. Tall buildings with large populations, such as high-rise offices (particularly those designed for phased evacuation), may benefit most from the use of lifts for emergency evacuation. Lower rise, but high population buildings, such as airports, stations and shopping complexes are also likely to benefit from the use of lifts and escalators as part of their emergency evacuation provision.

4.3.1.1.1 Evacuation strategy

The evacuation strategy in a building can have a significant influence on the potential use and benefits of lifts/escalators for emergency evacuation. Most buildings adopt one of the following evacuation strategies:

- simultaneous
- phased
- other, eg zoned or progressive horizontal evacuation (PHE)

Buildings using simultaneous evacuation strategies which also have high occupant numbers and densities may show an improved evacuation performance if lifts/escalators are used for emergency evacuation. Those with low occupant numbers and densities are unlikely to benefit significantly.

In a phased evacuation, usually one or two floors are evacuated at a time, starting with the floor where the fire is situated, and working up the building. This ensures that people in an area of greater risk (ie the fire floor or just above) are not trapped on their floor because the stairs have become blocked by people from other floors (where the risk was less). Stairs used for phased evacuation will often be fewer in number and narrower than stairs used for simultaneous evacuation.

Buildings adopting phased evacuation (or defend in place) are likely to be high-rise (above 30 m) and may be offices or residential. For these buildings each floor is a compartment floor, with a good degree of physical separation between successive floors, and between each floor and lobby-protected stairs. Lift lobbies are also protected by fire doors. These buildings may benefit significantly from the use of lifts for emergency evacuation. Escalators may also be beneficial for the evacuation of lower floors, especially if occupant numbers are high, for example, in a podium.

In a zoned or PHE, building occupants are moved away from the fire but remain on the same level. They are separated from the fire either by distance and/or by compartment walls. Buildings that use a zoned or PHE strategy, such as airports, shopping complexes and hospitals, may benefit from the use of escalators (travelators) and/or lifts for emergency evacuation in zones or compartments away from the zone or compartment of the incident or fire.

4.3.1.1.2 New buildings

For new buildings, it is relatively easy to include the emergency use of lifts and/or escalators for evacuation as a design objective at an early stage in the project and include appropriate systems as agreed with approval bodies following design team studies.

4.3.1.1.3 Existing buildings

For existing buildings, it may not be practicable to upgrade the physical precautions necessary for the use of lifts and/or escalators as means of escape, particularly from fire events. Alternatively, or in addition, it may be possible or necessary to upgrade the fire safety management strategy in order to make use of existing lifts/escalators under defined conditions, such as an ICE.

When reviewing an existing building, aspects to be considered should include:

- Does the building's structure comply with the functional requirements of the current Building Regulations [11]?
  - What is the period of fire resistance of the structure?
- What is the evacuation flow capacity of the emergency stairs for different parts of the building compared with those of the escalators and lifts?
  - Is the building (and its stairs) designed for simultaneous or phased evacuation? (Benefits may well be greatest in buildings designed for phased evacuation.)
  - Are one or more floors served by escalators where occupant numbers are likely to be high, so incorporation of escalators can provide a large temporary increase in evacuation flow capacity?
- Are the lifts/escalators modern or old?
  - Is it a collective lift (ie can it manage and prioritise multiple calls)?
  - Can it include additional modes of operation?
  - Does it have a 'non-stop' button or lift load non-stop facility?
  - Does it have a voice synthesiser?
  - Does it have position/out of service indicators at landings?
  - Is the lift's condition monitored?
  - Can it be controlled manually by a trained staff member?
  - What is the construction and what are operational modes for an escalator?
  - Can the escalator be reversed or used as a stair if stationary?
- Are the lifts/escalators protected?
  - Are lifts in a fire resisting shaft?
  - Are they lobby protected?
  - Is the lift shaft pressurised?
  - Are the lifts protected against flooding?
  - Are escalators in a fire resisting enclosure?
  - If in a non-fire resisting enclosure, are escalators designed to be sealed over by shutters between floors in a fire or other emergency?

- Are there alternative or protected power supplies to lifts?
  - Is there a standby power supply for all lifts?
  - Is the power supplied to all lifts from two different substations?
  - Is the lift power supply independent of the building power supply, protected and routed up the lift shaft?
  - Do lifts include their own back-up power supplies (batteries)?
- Where are the lifts positioned relative to the protected escape stairs?
  - Are they next to the stairs and both in a protected shaft/enclosure? (Stairs and lifts together allow occupants to switch evacuation mode easily.)
  - Are they in a different location, some distance from the escape stairs? (Stairs and lifts in different locations may mean that it is less likely for a single incident to take out all the means of escape, but can mean that occupants are less aware of alternative escape routes.)

4.3.1.2 Building environs

A building's environs, such as its location (city centre, urban, rural etc) and neighbours (high-rise, iconic or strategically important buildings) should be considered. This can influence fire safety and safety from non-fire events through the effect of events in adjacent buildings.

A number of other factors may affect the potential need for lifts and escalators for emergency evacuation. These factors may include:

- Location – buildings in a capital city and other urban locations may experience an increased risk of events where the use of lifts or escalators for emergency evacuation may be beneficial.
- Neighbours – iconic, tall and/or strategically important neighbouring buildings may increase their risk from terrorist attack, and hence the desirability of lifts/escalators for emergency evacuation in adjacent buildings in the case of imminent catastrophic events.
- Transport routes – proximity to transport routes and interchanges, such as airport approaches and stations, may increase the risk of events where the use of lifts or escalators for emergency evacuation may be beneficial for immediate and rapid evacuation.

4.3.1.3 Occupant characteristics

Occupant characterisation, ie the type of occupancy, the building population and its distribution, the likelihood of the fire alarm being raised manually, and the type of fire detection and alarm system should also be considered [8].

The implications and potential benefits of incorporating lifts/escalators into an emergency evacuation strategy are dependent upon the basic 'design behavioural scenario' of the occupancy which involves combinations of these occupancy factors. The main design behavioural scenarios are:

- occupants awake and familiar with the building and systems, and occupant densities generally low, eg offices
- occupants awake and unfamiliar with the building and systems, eg retail or assembly
- occupants asleep and familiar with the building, eg domestic dwellings
- occupants asleep and unfamiliar with the building and systems, eg hotels and hostels
- occupants asleep and with limited mobility, eg residential homes, healthcare premises.

When considering the use of lifts/escalators for emergency evacuation, there are several occupancy factors that should be reviewed. These occupancy factors include:

- physical ability of the occupants
- occupant numbers/population density
- reaction times
- occupants' familiarity with the building's layout and emergency procedures
- occupants' willingness to wait for a lift.

4.3.1.3.1 Physical ability of occupants

Another issue is the physical ability profile of the occupants. If there are many people in the building with disabilities related to movement, the use of lifts for the emergency evacuation of all occupants may result in a significant reduction in the time for evacuation. If lifts are used for the emergency evacuation of all occupants, there should be no need to provide specific facilities for disabled occupants. However, in such situations, evacuation times are likely to be long (depending upon occupant numbers) so that the extent of protection/enclosure of lifts may become a more important consideration (for example, in residential homes for the elderly and healthcare premises).

Occupant age profile can have an impact on the ability of occupants to use stairs during emergency evacuation. If occupants are generally healthy and young adults, stairs may be perfectly suitable for the vast majority of them. If many occupants are elderly or children, then the use of lifts as part of the means of emergency evacuation may be beneficial. Another issue is that slowly moving individuals on stairs may restrict the flow of more able-bodied occupants and decrease flow capacity. In practice this may not be a serious problem unless stairs are very narrow. If the occupant density on the stairs is low then able-bodied occupants are able to overtake slower individuals who are then able to evacuate at their own pace in the protected stair. If occupant density on the stair is high, the flow rates and travel speeds are low owing to the congestion, so slow individuals do not significantly affect the flow rate.

It is already common practice to utilise lifts for the evacuation of people with disabilities in an emergency [3] and this can result in a significant reduction in the overall time for evacuation. If lifts are used for the emergency evacuation of all occupants, then priority should given to those who are unable to use stairs, and consideration should be given to how these priorities would be managed in an emergency situation.

4.3.1.3.2 Occupant numbers/population density

For buildings with large occupant numbers and density, the use of lifts/escalators for emergency evacuation may result in greater reductions in the time for simultaneous evacuation. For buildings with a small occupancy, escape time is likely to be limited by travel distance (horizontal and vertical) and so the additional flow capacity provided by lifts/escalators is unlikely to have a significant effect.

Low-rise buildings with potential large occupant numbers and densities (awake and unfamiliar) are likely to show reductions in evacuation time. Another advantage is that occupants use escalators and lifts as part of their normal circulation patterns and are more likely to use them (and ignore emergency stairs), especially during the early stages of an incident.

For low-rise office (awake and familiar) buildings, occupant densities and numbers tend to be low compared with escape route flow capacity, so benefits are likely to be less. For high-rise office buildings, especially those designed for phased evacuation, although occupant densities may be relatively low, occupant numbers are high, so that vertical escape routes may rapidly become flow limited during a simultaneous evacuation. Stair use may also become restricted when the fire and rescue service arrives and deploys in a staircase to deal with an incident. Sleeping risk occupancies also tend to have relatively low occupant numbers and densities unless they are high-rise.

4.3.1.3.3 Reaction times

People's reaction times (pre-movement times) can also have a significant effect on their ability to use or benefit from the use of alternative modes of evacuation or evacuation procedures. If the reaction time of occupants is fast, there is a greater chance that they will be able to use multiple modes of evacuation or event-specific evacuation procedures. This is because all or most evacuation routes are likely to be usable during the early stages of an incident. Also, short reaction times can result in large numbers of people entering escape routes within a short time period, which can lead to congestion.

If multiple escape routes (including lifts, escalators and stairs) are used, this reduces the risk of congestion and reduces total evacuation times. This is particularly the case if the building is the occupants' place of work and they are awake and familiar with the building and systems. Where occupants are awake but unfamiliar with the building and systems, obtaining a short reaction time depends on the type of alarm system and the intervention of trained staff, and therefore upon a high standard of fire safety management,

If, however, the reaction time of occupants is slow (including sleeping occupants), then the use of alternative modes of evacuation becomes more problematic and the benefits less obvious. For able-bodied occupants of sleeping type premises (both familiar and unfamiliar), slow and highly variable reaction times result in a low probability that stairs will become congested. This means that evacuation times are more dependent upon reaction times and travel distances than on flow time/queuing. Also, with slow reaction times, there is a greater probability that escape routes other than emergency stairs will become unusable (depending upon the extent of enclosure/protection for escalators and lifts).

4.3.1.3.4 Occupants' familiarity with the building

The layout knowledge of occupants (familiarity) can have a significant effect on their ability to use alternative modes of evacuation or evacuation procedures. If all are familiar with the building, there is a greater chance that they will be able to choose between multiple modes of evacuation or use event-specific evacuation procedures. This is particularly the case if the building is the occupants' place of work and they have been trained in its specific evacuation provisions and procedures. If, however, few occupants are familiar with the layout of the building or if way-finding or visual access is poor, then it may be difficult for occupants to be aware of or use alternative modes of evacuation.

However, the degree of familiarity that occupants have will vary. Some occupants may not be familiar with the building layout at all; others may be familiar with the building layout (since they are frequent visitors) but not necessarily with the alternative potential modes of evacuation in an emergency. In these cases, and especially in cases where way-finding or visual access is poor, it will be more difficult for occupants to be, or become, aware of such alternatives. Where escalators or lifts provide an obvious and rapid means of escape for occupants otherwise unfamiliar with a building, their use may also be beneficial.

4.3.1.3.5 Occupants' willingness to wait for a lift

The length of time occupants are willing to wait for a lift is likely to depend on a range of factors including:

- How threatened they feel.
- What they know about the performance of the lift system.
- Are they (aware of) making any progress?
- What information they are getting about how long they are expected to wait.
- Are they on their own or with others?
- Do they perceive someone to be in control?
- Do they have confidence in those perceived to be in control?
- Can they easily get to a staircase?

Communication between those responsible for managing the evacuation and those waiting for a lift is clearly very important. There should be clear procedures to communicate with those waiting for lifts, whether from those in the emergency control centre, by fire wardens on each floor and/or by message boards indicating lift function/performance.

The length of time people should be expected to wait for evacuation will vary from building to building and should be agreed in the QDR meeting. There is relatively little research in this area, but there is some precedent from certain buildings/building types. For example:

- occupants of stadia have been observed to become agitated if they do not enter a free flowing exit system in eight minutes or less at the end of an event
- some visitor attractions have queuing times of up to an hour
- some high-rise office occupants have been willing to wait for up to 30 minutes or more for an evacuation lift during evacuation exercises.

4.3.1.3.6 Summary of occupant characteristics and their implications for the emergency use of lifts or escalators

In summary, it may be easier to introduce and manage lifts/escalators for emergency evacuation where:

- layout knowledge of the occupants is good or unfamiliar occupants are managed by well trained staff
- reaction times are shorter.

Examples of occupancies that may satisfy these criteria could include offices and retail stores.

It may be of greatest benefit to introduce lifts/escalators for emergency evacuation where:

- occupant densities and numbers are high
- occupant densities are low but buildings are high-rise
- the occupant profile includes a significant proportion of elderly and/or mobility impaired people on floors other than the ground floor.

The effective use of lifts and escalators as alternative means of escape should be considered in light of the natural flows created in a building, the natural tendency for occupants to use routes with which they are familiar and in which they have confidence with regards to their safety, and the likely impact that management of the evacuation process by trained personnel can have. Their introduction as alternative modes of emergency evacuation is likely to be more effective in cases where the layout and knowledge of evacuation procedures is already good. Offices may be a good example of this. In cases where occupants are not familiar with the building and/or evacuation procedures, and therefore unaware of options for evacuation, the introduction of lifts/escalators as alternative modes can still be effective, but in such cases the management of the evacuation process will become even more important.

4.3.1.3.7 Other factors

As well as the occupant characteristics above, other human factors are also critical to the effective use of evacuation provisions in an emergency. These require careful consideration during the design and commissioning of new systems, for example:

1. Occupants are more likely to use evacuation routes they have knowledge of and can visualise. Evacuation routes should be simple and clearly signed to aid orientation and way-finding during an emergency.
2. Occupants should be trained and encouraged to use alternative means of escape during drills and evacuation exercises, and ideally during the normal use of the building. This will help avoid 'learned irrelevance' where occupants are unaware of alternative means of escape in an emergency.
3. Occupants are more likely to be prepared to wait for a lift or make an informed choice of exit route if they can see how each is performing and switch easily between them. Therefore, if an escape staircase is co-located with a bank of lifts in the same protected shaft/enclosure, occupants have a clear choice of route. Other escape stairs may be located away from lifts owing to travel distance considerations and will also help the resilience of the vertical escape routes.

4. Occupants should be protected and feel protected when they are waiting, perhaps for some time, for a lift to arrive. Lift lobbies should be large enough to accommodate anticipated occupants who are expected to use the lift, and designed so as not to impede other routes.
5. Communication regarding the progress of the evacuation to persons waiting for lifts is an important issue, as is consideration of the duration of time that persons might be prepared to wait for a lift before choosing an alternative means of escape.

4.3.1.4 Management of fire safety

Managing fire safety is the whole process throughout the life of a building, starting with the initial design, which is intended to minimise the incidence of fire and to ensure that, if a fire does occur, appropriate fire safety systems (including active, passive and procedural systems) are in place and are fully functional [7]. The role of management in the emergency use of lifts or escalators for evacuation is critical.

Effective management of fire safety can contribute to the protection of the building occupants in many ways:

- by working to prevent fires occurring in the first place
- by being aware of the types of people in the building and any special risks or needs (such as people with disabilities)
- by ensuring that all of the fire safety measures in the building are kept in working order, and in particular that the means of escape are always available
- by training staff and organising the evacuation plan so that the evacuation is effectively managed, and ensuring that occupants leave quickly if a fire occurs
- by taking command in the event of a fire until the fire service arrives.

The use of lifts/escalators for emergency evacuation has implications for the last four points in the list above and this is where the role of management is most significant.

PD 7974 Part 6 [8] provides guidance on the role, application and effectiveness of fire safety management procedures during evacuations involving different design behavioural scenarios and building types. BS 5588 Part 12 [7] provides guidance for the management of fire safety over the lifetime of the building, including guidance for designers to ensure that the overall design of a building assists and enhances the management of fire safety. It identifies 16 components of fire safety management, for each of which there is one of three levels of management. Level 1 provides the highest standard or quality of management and level 3 the lowest (see Table 2).

According to BS 5588 Part 12 [7], level 1 is achieved when all components lie in the level 1 column. Level 2 is achieved when the components lie in level 1 or 2. If the ownership of the property is not known, or uncontrolled change of use is possible, then level 3 should be assumed throughout.

Table 2 Levels of fire safety management

Management factor	**Management level**		
	Level 1	**Level 2**	**Level 3**
Ownership	Known	Limited	Not known
Manager's role	Single responsible person *	Known responsible persons	Not known
Resources/authority	Good	Average	Minimal/none
Staffing level (staff-occupant ratio)	High *	Medium	Low/none
Fire training	Good	Average	Minimal/not known
Security	Good	Medium	Minimal
Work control (eg repairs to structure)	Good	Average	Minimal/none
Communications procedures	Good	Average	Minimal
Maintenance/testing of fire safety systems	Frequent	Occasional	Minimal
Liaison with fire & rescue services	Good	Average	Minimal
Contingency planning	Good	Adequate	None
Degraded systems planning	Good	Adequate	None
Abnormal occupancy planning	Good	Adequate	None
Testing/auditing of management system	Fully independent	In-house	Minimal/none
Risk management	Good	Poor	None
Fire load management (contents control)	Good	Poor	None

* Note in Table 2: In the context of using lifts/escalators for emergency evacuation, there may be circumstances where the use of the building precludes some of the requirements for level 1 management. These exceptions include:

- Manager's role – in multi-tenant buildings, such as high-rise offices, airports and shopping complexes, there may be several known Responsible Persons under the Fire Safety Order. However, for the emergency use of lifts or escalators for evacuation, there should be a single manager responsible for evacuation.

- Staff level (staff-occupant ratio) – for buildings to which the public have access, such as underground stations, airports and shopping complexes, the staff ratio may be medium or low.

For lifts or escalators to be used for emergency evacuation, the management level in the building should be level 1. If, as in the notes to Table 2, there are only one or two exceptions to a level 1 management regime, organisation specific cases can be made and evidenced for equivalency to management level 1. There should also be robust evacuation procedures for provisions such as marshalling. For example, there should be a marshall in each lift or in each lift lobby to ensure that lifts are used efficiently and safely (ie control of the number of people entering the lift).

Buildings where a level 3 fire safety management is achieved should not consider the use of lifts or escalators for evacuation in fire and other emergencies.

4.3.2 Establishment of fire safety objectives

Since the QDR process described in this guidance is focused on the use of lifts and/or escalators for emergency evacuation, the fire safety objective of this QDR process is by default, lift safety. However, it is important to identify in which type(s) of event the use of lifts and/or escalators will be intended:

- ICE

and/or

- fire events.

See section 4.3.3 below.

4.3.3 Integrated evacuation strategy

In general, if lifts and/or escalators are to form part of the emergency evacuation from a building, they should form part of and be included in an integrated evacuation strategy. Therefore, they should form part of the design team studies (for new or existing buildings) for submission to the relevant approval authority(s).

4.3.3.1 Non-fire (ICE) events

Where lifts and escalators form part of the normal access and egress from a building, they may already be used for the emergency evacuation of building occupants during non-fire events.

For iconic, high profile or strategically important public or transport buildings, consideration should be given to the different types of non-fire event and the necessary evacuation plans, procedures and staff training required to provide effective evacuation from a range of these non-fire events. Lifts and escalators may be particularly beneficial for ICE events. Imminent Catastrophic Events are where there is some warning of a significant threat to a building and so rapid simultaneous evacuation of the whole building is the primary objective. The provision of lifts and/or escalators for emergency evacuation from ICE events may also increase resilience against other extreme events.

4.3.3.2 Fire events

Whether lifts should be used for the emergency evacuation of the general building population from fire events requires additional considerations to their use for ICE events. Lifts and escalators are not normally used as means of escape from buildings in the event of fire. Indeed, the received wisdom of occupants from fire signs and fire safety training in buildings is that lifts should not be used in the event of fire in a building. Lifts used during a fire event have the additional risks associated with having fire hazards present in the building and potentially a fire that is spreading between compartments (see guidance on piston effect and pressurisation below). Therefore, the use of lifts for emergency evacuation from fire is likely to require additional fire precautions when compared to those used solely for emergency evacuation from ICE events.

4.3.3.3 Piston effect/pressurisation

A lift car moving in a lift shaft will drive air flows throughout a building. There are basically three ‘effects’ that must be considered:

- the ‘piston effect’ where air being pushed out of the lift shaft creates pressure differences forcing air from the shaft and out of the building, through lobbies and main floor areas
- the ‘pump effect’ where the movement of the car up and down the shaft alternately draws smoke into the shaft when it is under negative pressure relative to the floor areas and/or lobbies and then expels the smoky air from the shaft when the pressure within the shaft is positive relative to the floor areas and/or lobbies
- transport of smoke within the lift car, from floor to floor.

Analysis indicates that the most significant consequence of the lift movement is to push smoke from the ‘lobby’ area into the adjacent floor area. The transportation of ambient smoke from floor to floor by the pump effect is much less, resulting in smoke concentration on floors remote from the fire being several orders of magnitude lower than the floor of fire origin.

If the lifts are to be used during emergency evacuation from a fire, consideration should still be given to the need for pressure differentials in the lift shaft to prevent the ingress of smoke into the lift shaft [11].

4.3.4 Identification of additional fire and safety precautions

4.3.4.1 Physical fire and safety precautions

There is a significant range of potential additional fire precautions that could be adopted in the use of lifts and/or escalators for emergency evacuation. These include:

- building layout
- lift systems
- escalator systems
- building communication systems
- fire (and other emergency) detection and alarm systems
- closed circuit television.

4.3.4.2 Building layout

The layout of the building can help to enable the use of lifts for emergency evacuation. For example, having an escape stair co-located with a bank of lifts can have several benefits:

- it is easy for occupants to switch between stairs and lifts
- those waiting for lifts have an alternative available from the same lobby
- occupants can assess the relative efficiency of each method of evacuation.

Some of the benefits of co-located lifts and stairs may not be available in multi-tenanted high-rise buildings where re-entering a lift lobby from a shared escape stair may not be possible because of security considerations.

On the other hand, separating evacuation lifts and escape stairs may increase their protection and robustness against fire and other similar types of event. For example, separation between escape stairs and the banks of lifts will mean that it is less likely for a single event to compromise both/all vertical escape routes at the same time. In some buildings with multiple banks of lifts it may be possible to co-locate an escape stair and separate the banks of lifts. In other buildings, travel distance considerations may mean that it is possible to co-locate one escape stair with the bank of lifts whilst other escape stairs are naturally separated from them and each other.

4.3.4.3 Protected lobbies

Lift lobbies can play an important role in protecting people while they wait for an evacuation lift. The role and dimensions of lift lobbies may vary from building to building. For example, in a tall building:

- where lifts are only used for ICE events and stairs are the initial vertical means of escape from all floors until a protected transfer floor is reached and then occupants use shuttle lifts for the rest of their journey, the use of lifts for emergency evacuation may not require the general provision of protected lift lobbies
- where lifts are used for fire events from all floors, including the fire floor, then consideration should be given to the provision of lobbies to protect those waiting for a lift. (However, for human factors and other reasons, it may be advisable for people on the fire floor to only use stairs for their means of escape.)

If lobbies are required to protect occupants waiting for an evacuation lift then consideration should be given to the sizing of the lobby. The size of the lobby should be based on the reasonable worst case population and a reasonable floor space factor.

The reasonable worst case lobby population may be relatively small in some buildings with relatively low populations, eg residential buildings. For other relatively high population buildings, such as offices, the reasonable worst case lobby population may be relatively high and be highly dependent on the number of people who choose to and/or have to wait for evacuation lifts. A limited number of evacuation drills and experiments indicate that in tall office buildings approximately 50% (+/- 10%) of building occupants choose to use the lifts for vertical evacuation. This may vary from building to building and so an assessment should be undertaken during the design phase of the project and verified by evacuation exercise(s) after completion of the project.

The other important factor in sizing any lift lobby is a reasonable floor space factor. The floor space factor chosen should take into account the amount of time that people may expect to spend in the lift lobby. This waiting time may be extensive and be up to an hour on some floors in some buildings. A reasonable floor space factor may lie between two and four people per m^2 of floor area and guidance on different occupant densities found in queues can be found in Fruin [23].

4.3.4.4 Lift systems

Consideration of the additional protection measures for the use of lifts for means of escape should include:

- communication systems
- protection to the lift
- different operational modes during an emergency.

There should be robust systems for two-way communication between those responsible for managing evacuation and those evacuating. Some of these systems may form part of the lift systems and others may be dedicated systems. For example, for lift systems there should be two-way communication between the:

- emergency control room and lift car
- emergency control room and lift machine room
- emergency control room and lift lobby (these systems should comply with BS 5839 Part 9 Type B [17]).

Where lifts or escalators are proposed for emergency evacuation from fires, consideration should also be given to the need for:

- compartmentation to lift shafts
- ventilation (pressurisation to BS 5588 Part 4 [11])
- power supplies should (see BS 5588 Part 8 [3]):
  - have an alternative back-up if the normal power supply fails
  - be protected from the effects of fire and water.

There should also be means of monitoring lift function and shaft conditions from the emergency control centre.

4.3.4.5 Lift operating mode

Emergency evacuation mode options for lifts can include:

- peak down mode
- ignore all up calls
- top call first
- non-stopping on the way down, and/or
- non-stopping at the fire floor.

'Peak down mode' is used at the end of the working day in office buildings to facilitate the efficient egress of most occupants over a relatively short period of time. This mode may provide a good starting point for the development of a lift operating mode for emergency evacuation. However, peak down mode still allows occupants to access the building from the ground floor, travel up the building and move between floors. The peak down mode should be modified for emergency evacuation and some of the potential modifications are discussed below.

'Ignore all up calls' means that the evacuation lifts will not respond to any up calls. This should increase the quality and quantity of service for floors with a down call. It may mean that if someone places an up call only, they may be waiting for a lift that will not arrive. This can be addressed through training and/or programming the lift to respond, but only travel down to ground floor once the occupant has entered.

'Top call first' means that the lifts will prioritise lift calls from the top floors. When a floor has been evacuated, the lifts will then prioritise the next top call and so on. This is a very efficient way of reducing the evacuation time for those at the top of the building, but may lead to:

- extended waiting times for those on lower floors using lifts and/or
- lack of service for all floors except the top floor.

'Non-stopping on the way down' can be a way of avoiding delays due to the lifts stopping at additional floors until it is full. This may improve the quantity of service because lift door opening and closing times can form a significant proportion of a lift's journey time. This may also mean that on the last call for a floor, the lift may travel to the ground floor with only a partial load of occupants.

If lifts are used for means of escape from fire, they may be programmed not to travel to any floor where the fire alarm system has operated. This should mean that the lift will not stop at a fire floor and so will prevent occupants being exposed to fire hazards. It may also mean that people on the fire floor are waiting in a lift lobby for a lift that will not arrive. This also applies to people on other floors where smoke leakage is sufficient to activate detectors or where occupants see smoke and operate a manual call point. This can be addressed through training, and programming the lift to avoid only those floors where automatic detectors have been activated.

Modern lift systems allow a significant amount of flexibility and functionality in developing and providing an efficient, safe and reliable mode for emergency evacuation. These modes will vary from the normal operating modes for the building and may vary between ICE and fire events. They can also become quite sophisticated. For example, the lifts can be programmed to service a range of floors at the same time rather than just the floor with the top call. This will not change the overall evacuation time, but will ensure that more occupants waiting for lifts will see some progress and have increased confidence in their operation.

4.3.4.6 *Means of freeing those trapped in a stopped lift*

It is possible for lifts to become trapped between floors. Some procedures for freeing occupants during normal operations can involve calling out lift engineers with an inherent time delay. For lifts used for emergency evacuation, consideration should be given to providing means for rapidly freeing those trapped in a lift stuck between floors.

4.3.4.7 *Escalator systems*

Escalators should be subject to many of the same considerations as lift systems and in particular:

- communication systems
- protection to the escalator
- different operational modes during an emergency.

The need for communication systems between individuals is much less for escalators and a general building communication system may suffice (see below).

If escalators are to be used in the event of a fire, protection should be provided to ensure that compartmentation is not compromised and that those using the escalator are protected from fire hazards. Depending on the type of building this may comprise fire shutters, fire doors and/or a smoke control system.

There should be means of stopping an escalator both locally and in the emergency control centre, in the event of circumstances with the potential to cause a crush incident, eg queues forming near the discharge point of the escalator.

There should also be means of monitoring lift/escalator function and shaft conditions.

Consideration should also be given to the operating mode of escalators during an emergency evacuation. Options can include:

- normal operation with staff preventing access to escalators moving in the opposite direction to escape
- stopping escalators moving in the opposite direction to escape and allowing them to be used as stairs
- reversing the direction of escalators moving in the opposite direction to escape.

Option 1 may be the quickest and simplest to implement. Option 2 may increase evacuation capacity, but consideration should be given to the fact that the rise of the steps of escalators is not ideal for their use as stairs. Option 3 may ultimately result in the highest egress capacity, but will take more time and additional staff resources to achieve.

4.3.4.8 *Building communication systems*

Where lifts and/or escalators are used in an emergency evacuation there may be a need to communicate with the general building population. Consideration should be given to the provision of a voice alarm system to BS 5839 Part 8 [16]). Some buildings with large populations who are unfamiliar with the building may incorporate a voice alarm system already.

4.3.4.9 *Fire (and other emergency) detection and alarm systems*

From the paragraphs above, it is clear that the use of lifts and/or escalators for emergency evacuation is likely to involve more interfaces between different building services systems. This is likely to further increase the complexity and importance of the cause and effects matrices for the fire detection and alarm system, ventilation system and lift/escalator system(s).

4.3.4.10 *Closed circuit television and other security and building management systems*

Closed circuit television and other security and building management systems may provide information on the number, location and density of occupants. This additional information may be helpful in the management of emergency evacuation using lifts and/or escalators.

Table 3 below sets out some combinations of physical precautions that should be considered during a QDR of emergency evacuation provisions.

Table 3 Summary of physical precautions that may be considered

	New buildings	**Existing buildings**
Non-fire events The emergency use of lifts or escalators for simultaneous rapid evacuation from an Imminent Catastrophic Event (ICE)	Lifts and escalators can be incorporated into an ICE evacuation strategy and should be provided with a high degree of reliability and protection. Systems which will help facilitate their use for simultaneous evacuation in new buildings include: • lifts should comply with BS EN 81 [13, 18 or 19 depending on the type of lift] • emergency voice communication system to BS 5839 Part 9 Type B [17] for all lift halls • voice alarm system to BS 5839 Part 8 [16] • new lift operating mode for simultaneous evacuation • alternative lift power supplies	Systems which will help facilitate the use of lifts and/or escalators in existing buildings are similar to those for new buildings, with the exception that: • lifts may be 'modern', 'protected' and have an 'alternative power supply' (see section 4.3.1.1 on Building characterisation) • a public address system used in the normal operation of the building may be used instead of a voice alarm system • increased protection to power supplies may be practicable where an alternative power supply is not already provided These systems may be appropriate for ICE events in existing buildings as the use of lifts and/or escalators should increase safety (by reducing simultaneous evacuation time) and because in an ICE scenario there should be no hazard present during evacuation.
Fire events The emergency use of lifts and/or escalators for the evacuation of large number of people	Lifts and/or escalators incorporated into the fire evacuation strategy for new buildings should be provided with a high degree of reliability and protection. Systems should be the same as for ICE events above except that: • All evacuation lifts to comply with BS 5588 Part 8 [3] and be clearly signed. Except for low-rise/large footprint buildings, such as hospitals, airports and shopping centres, where lifts with alternative power supply in compartments away from the fire may be used if they are adequately protected and managed. • Any fire-fighting lifts should be dedicated and suitably signed.	Lifts and escalators can be incorporated into the fire evacuation strategy for an existing building and should be provided with a high degree of reliability and protection. Systems which will help facilitate their use for simultaneous evacuation in the event of fire are considered to be the same as those for new buildings. This is because the building should already be designed for evacuation due to fire, and the introduction of an alternative evacuation strategy involving lifts and escalators for means of escape from fire should be undertaken in such a way that it increases safety and does not expose occupants to additional risks. [Note: Any alternative evacuation strategy involving lifts and/or escalators or means of escape will be subject to a fire risk assessment under the Fire Safety Order.]

4.3.4.11 *Fire safety management*

In addition to the physical precautions above, and to facilitate their use, additional fire safety management provisions will be appropriate. As a minimum, for the use of lifts/escalators for emergency evacuation, fire safety management provisions should include:

- if the evacuation plan for a building involves more than one type of evacuation, eg phased evacuation for fire events and simultaneous evacuation for Imminent Catastrophic Events, then level 1 fire safety management should be adopted
- if there are multiple modes of evacuation, ie stairs and lifts/escalators, then level 1 fire safety management should be adopted.

In either or both situations above, a strong case should be made for the emergency use of lifts or escalators for evacuation and this should be stated in the fire safety manual.

Buildings with level 2 or 3 fire safety management should not use lifts/escalators for emergency evacuation of general building occupants. Some organisations, such as airport operators, with level 2 fire safety management may also achieve level 1 in most respects (see section 4.3.1.4) and so may make a case for fire safety management at level 1.

4.3.4.12 *Evacuation procedures*

In buildings where lifts and/or escalators are used for emergency evacuation, clear evacuation procedures will be required. A range of evacuation protocols should be considered and the same or different evacuation protocols may be used for fire or other events such as Imminent Catastrophic Events (ICEs).

In high-rise office buildings:

- For ICE events, occupants on all floors may be allowed to choose between evacuation lifts and stairs.
- For fire events, those on the floor of fire origin may be instructed to use stairs only so that they are not waiting for a lift in a lobby adjacent to a potentially developing fire situation. If a full phased evacuation becomes necessary, occupants on other floors may be allowed to choose between evacuation lifts and stairs. Alternatively, all occupants might be directed to use the stairs as far as protected transfer floors where they can transfer to shuttle lifts for the rest of their journey.

These types of evacuation protocol may be difficult to plan and implement in many mixed use or multiple tenanted buildings.

4.3.4.13 Implementation of additional fire safety management provisions

In addition, the adoption of dual/multiple evacuation strategies is likely to require detailed consideration of, and changes to:

- fire training
- communications procedures
- liaison with fire and rescue services
- contingency planning
- risk management
- maintenance/testing of fire safety systems
- degraded systems planning.

In particular, consideration should be given to the potential need for and procedures to rescue people trapped in a stuck lift.

4.3.5 Identification of acceptance criteria and methods of analysis

For lifts and/or escalators used solely for emergency evacuation from ICE events, the main acceptance criteria might include:

- A significant reduction in overall evacuation time.
- No significant additional risks introduced during emergency evacuation.
- Precautions to prevent or mitigate any additional risks (eg person stuck in a lift or crush incidents with escalators).
- No reduction in the redundancy or diversity of the system should one means of vertical evacuation fail or be unavailable in an incident. For example, if the evacuation lifts fail, there should not be a reduction in stair width provision.

For lifts and/or escalators used for emergency evacuation from fire events there are likely to be additional acceptance criteria. For example, the proposed evacuation strategy should also demonstrate equivalency in terms of:

- Lifts and/or escalators should be protected to the same degree as evacuation lifts (BS 5588 Part 8 [3]). This equivalent protection could be achieved by ‘virtual compartmentation’, for example, in shopping malls or airport terminals, where the lift may be a large distance away from the fire. The location of the fire would need to be known to be remote from the lift, and there would also need to be an assurance that the lift could not lose power as a result of the fire.
- Lifts and/or escalators should not compromise the achievement of other functional requirements by undermining other fire protection

systems incorporated in a building, eg escalators passing through a compartmentation floor.

- There should be effective means for communication between building management and occupants to provide general warning and instruction (eg BS 5839 Part 8 [16]).
- There should be effective means for communication between building management/emergency control/lift control room and occupants in lifts and refuge areas (eg BS 5839 Part 9 Type B [17]).

Owing to the nature of the challenge, it is expected that the use of lifts and/or escalators for evacuation will be in addition to the normal means of escape provision.

4.3.6 Establishment of evacuation scenarios for analysis

The number of possible evacuation scenarios in a building can be very large with neither the data nor resources available to quantify them. Therefore, detailed analysis and quantification of specific scenarios should be limited to the most significant scenarios.

The characteristics of an evacuation scenario for analysis purposes should include a description of the following where appropriate:

- the type of event (ICE or fire)
- the number and location of the occupants of the building
- whether occupants are familiar with the building
- whether the occupants are trained in the emergency procedures for the building
- whether the occupants are alert (awake or asleep)
- the mobility of the occupants and the number of occupants whose mobility is impaired
- the evacuation strategy and provisions:
  - for a code compliant solution
  - with additional provision of lifts and/or escalators
- the performance of each safety measure.

Chapter 5

Quantitative analysis and comparison with acceptance criteria

Quantitative analysis will normally be necessary to understand the benefits and additional fire precautions/procedures for the emergency use of lifts or escalators for evacuation. Quantification should be undertaken irrespective of the size of the development, because for certain smaller developments, such as medium-rise offices, the use of lifts for emergency evacuation of the general population can increase the overall evacuation time.

The quantitative analysis may be deterministic or probabilistic and may use simple evacuation models or discrete computational evacuation models. In all cases, the presentation of the results of analysis should also include:

- the limits of applicability of the model(s)
- any key assumptions, such as the proportion of occupants choosing lifts and stairs
- consideration of the data used to err on the side of safety
- consideration of the robustness of the conclusions of the analysis, eg through sensitivity analysis.

The quantitative analysis and comparison with acceptance criteria should follow the procedures set out in BS 7974 [9] and the data and methods set out in PD 7974 Part 6 [8] (see also Annexes B and C of this guide).

Chapter 6

References

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[2] 'Occupant Behaviour, Egress and Emergency Communication' (NIST NCSTAR 1-7), Averill JD, Mileti DS, Peacock RD, Kuligowski ED, Groner N, Proulx G, Reneke PA and Nelson HE.

[3] BS 5588 Fire precautions in the design, construction and use of buildings, Part 8 Code of practice for means of escape for disabled people, British Standards Institution.

[4] BS 5588 Fire precautions in the design, construction and use of buildings, Part 5 Code of practice for fire-fighting stairs and lifts, British Standards Institution.

[5] E1400 Engineering Standards, London Underground Ltd.

[6] Firecode HTM 05-03 Part E 'Escape bed lifts', Department of Health, 2007.

[7] BS 5588 Fire precautions in the design, construction and use of buildings, Part 12 Managing fire safety, British Standards Institution.

[8] PD 7974 Application of fire safety engineering principles to the design of buildings: Part 6: Human factors: Life safety strategies – Occupant evacuation, behaviour and condition.

[9] BS 7974 Application of fire safety engineering principles to the design of buildings – Code of Practice, 2001, British Standards Institution.

[10] The Buildings Regulations 2000 – Approved Document B – Fire Safety – Volume 2 – Buildings other than dwellinghouses, 2006 Edition. Communities and Local Government.

[11] BS 5588 Fire precautions in the design, construction and use of buildings: Part 4 Code of practice for smoke control using pressure differentials, British Standards Institution.

[12] BS EN 81-73:2005, 'Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Behaviour of lifts in the event of fire', British Standards Institution.

[13] CIBSE Guide D, 'Transportation systems in buildings', Chartered Institution of Building Services Engineers, 2005.

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[15] BS 5656-2: 2004, 'Escalators and moving walks. Safety rules for the construction and installation of escalators and walks. Code of practice for the selection, installation and location of new escalators and moving walks.', British Standards Institution.

[16] BS 5839 Part 8: 1998, 'Fire detection and fire alarm systems for buildings. Code of practice for the design, installation, commissioning and maintenance of voice alarm systems', British Standards Institution.

[17] BS 5839 Part 9 'Fire detection and fire alarm systems for buildings. Code of practice for the design, installation, commissioning and maintenance of emergency voice communication systems', British Standards Institution.

[18] BS EN 81-1: 1998, 'Safety rules for the construction and installation of lifts. Electric lifts', British Standards Institution.

[19] BS EN 81-2: 1998, 'Safety rules for the construction and installation of lifts. Hydraulic lifts', British Standards Institution.

[20] HTM 05-02 'Guidance in support of functional provisions for healthcare premises', Department of Health, 2007.

[21] BS 5499, 'Safety signs and symbols', British Standards Institution.

[22] BS EN 81-72: 2003, 'Safety rules for the construction and installation of lifts. Particular applications for passenger and goods passenger lifts. Firefighters' lifts', British Standards Institution.

[23] Fruin, JJ, 'Pedestrian and planning design', Elevator World Inc, 1987 (revised edition).

Annex A

Current practice in the use of lifts and escalators

Lifts and escalators already form part of the means of escape in certain circumstances, for example, for:

- disabled occupants [3]
- certain high-rise offices [4]
- underground stations [5]
- some hospitals [6]
- some communications/air traffic control towers.

The following sections provide summaries of current practice in the emergency use of lifts for evacuation in buildings.

Means of escape for disabled persons

BS 5588-8: 1999 [3] deals with means of escape for disabled persons. It mentions the use of lifts but stipulates that they should only be considered for evacuation purposes if suitable safety measures have been included in the lift's design. Evacuation lifts are considered and recommendations made regarding the design features needed. These are similar in nature to the measures required for fire-fighting lifts. It is important to note that evacuation lifts are not to be reserved solely for use in the event of an emergency. They should also be used as regular passenger lifts but should not be used as goods/service lifts. This is to ensure that they can be brought into use as evacuation aids as quickly as possible.

BS 5588-8: 1999, with respect to lifts, includes, though not exclusively, the requirements that:

- evacuation lifts should be provided with an associated refuge
- any lift provided for the evacuation of disabled people should be either a fire-fighting lift or an evacuation lift
- an evacuation lift should conform to the relevant recommendations in BS 5810 and BS 5655-1 or BS 5655-2 (now BS EN 81-1 [18] or BS EN 81-2 [19])

- an evacuation lift should be clearly identified
- evacuation lifts, their associated machinery, construction (shafts, refuges, lobbies, etc), power supplies and evacuation routes should be afforded the same level of fire protection as required for the building itself
- evacuation lifts include an 'evacuation lift' switch to isolate lift landing call controls, defer all control to the lift car controls and activate the lift communication system, for operation of the lift by an authorised person

Installation and use of escape bed lifts in hospitals

Firecode Health Technical Memorandum (HTM) 05-03 Part E [6] provides guidance on the installation and use of escape bed lifts. Technical guidance is given similar to that outlined above. Of particular interest are the procedures that it specifies in order to ensure the safe use of escape bed lifts during a fire. These include the provision of lifts wardens to be present at each of the dependant floors, the lift control room and in the lift car itself. All wardens should be capable of communicating with one another in order to coordinate the evacuation as effectively as possible.

HTM 05-03 Part E [6] includes, though not exclusively, the requirements that:

- An agreed evacuation procedure should be in place for use by the lift wardens.
- A sufficient number of wardens be provided in order to carry out all of the tasks associated with the use of the escape bed lift. These duties are repeated below:
  - Lift wardens should be present on each floor containing a dependant department in order to coordinate the horizontal evacuation process and assess the need for vertical evacuation. This warden should notify the control point if the escape bed lift will be required.
  - A lift warden should be present at the control point of each escape bed lift or bank of lifts, in order to operate the control switch and to organise an orderly vertical evacuation, should it become necessary.
  - Lift wardens should man each escape bed lift car in order to operate the car in accordance with instructions received from the lift control point.
- A communication system should be in place so that the lift car, landings and machine room can all communicate with the control point, so that the control point can coordinate the evacuation as effectively as possible.

- Measures should be in place to minimise the effect of lift component failures and to ensure that, should a failure occur, an alternative vertical evacuation strategy is ready to be implemented.
- Regular drills should be carried out to test the procedure and ensure its continued effectiveness. The potential for lift failure should be considered in the drills undertaken.
- Sufficient escape beds should be provided for use with the lifts, in accordance with HTM 05-02 [20].
- Where an escape bed lift is one of a bank of lifts sharing a protected shaft, all other lifts in that bank should also be escape bed lifts. At least one additional escape bed lift remote from this shaft should be provided in order to satisfy HTM 05-02 [20].
- The escape bed lift should be located within a protected shaft.
- Associated machinery and the supply to that machinery should be protected against fire for a period not less than the period for which the lift shaft is protected.
- The lift car should comply with the requirements of BS 5655, and be designed so that its internal dimensions are sufficient to hold an occupied bed, its ancillary equipment, an attendant and the lift warden.
- The lift should be capable of running its entire length of travel in less than one minute.
- The lift should not be used for the transport of goods or refuse, and should include signage to that effect, in accordance with BS 5499 [21].
- The electrical systems should be resistant to failures and malfunctions of associated equipment, such that the functioning of the escape bed lift is not unduly affected by the failure or malfunction of a single component.

Fire-fighting lifts

Fire-fighting lifts have in the past been the only type of lift considered to be appropriate for use during a fire. These lifts are designed to be resistant to the physical effects of fire, as outlined in BS EN 81-72: 2003 [22]. Their design and installation should be resistant to electrical disturbance due to water ingress and should be enclosed in a construction possessing a suitable degree of fire resistance. BS EN 81-72: 2003 [22] also specifies the inclusion of a suitable communication system and escape facilities for use by fire and rescue personnel. These measures are reiterated in BS 5588-5: 2004 and their relevance to the practical aspects of fire-fighting lift usage further considered, particularly with respect to the control measures that need to be incorporated into fire-fighting lift design in order to ensure safe operation by the fire and rescue service.

BS 5588-5: 2004 [4], with respect to lifts, includes, though not exclusively, the requirements that:

- They are provided for both tall (>18 m above ground) and deep (≥10 m below ground) buildings.
- The installation conforms to BS EN 81-72 and BS EN 81-1 or BS EN 81-2, depending on the type of lift. These requirements include, but are not exclusive to:
  - The lift, and all the components associated with its function, being protected and capable of operation for a period equal to the period of fire protection required by the building structure.
  - The electrical components of the lift being protected from potential water ingress into the lift shaft and well, and being designed to be unaffected by malfunction at the landing call buttons.
  - The lift servicing every floor of the building.
  - The lift being capable of reaching the floor furthest from the fire-fighter access level in under 60 seconds.
  - The lift being designed to allow fire-fighters to be rescued or effect self-rescue in the event of the lift becoming immobilised.
  - A suitable intercom two-way speech system being included in the lift design.
  - The lift being protected against vandalism in vandal prone areas.
- Fire-fighting lifts operate normally until the fire-fighting lift switch is activated.
- The fire-fighting lift, once activated, operates in accordance with the method given in BS EN 81-72.

Reference numbers relate to the references in the main guidance document.

Annex B

The benefits of using lifts or escalators for emergency evacuation

This Annex provides information on the benefits of using lifts or escalators for emergency evacuation and discusses some of the issues that may affect their potential performance.

Lifts

An approximate calculation may be useful in estimating how quickly people can be evacuated by lifts. Suppose a lift can carry *N* people at a travel speed of v m.s^{-1} from a floor that is *H* metres above ground level. It takes *t* seconds for the doors to open and close, and roughly 1 second per person to enter/empty the lift when the doors are open. The time for a complete round trip by the lift, including loading and unloading, will be

$$t_{RT} = 2\left(\frac{H}{v} + t + N\right)$$

and hence the flow rate of people will be *N* divided by t_{RT}. Say H =30m, v=1.5m.s^{-1}, t =4s, N=12, then t_{RT} will be 68s, or a flow rate of ~0.2 people.s^{-1}. (These are nominal values, and not intended to represent any particular lift.) This is somewhat slower than able-bodied people using a typical stair might achieve (on stairs the travel speed is less, but the ‘carrying’ capacity is much greater and the flow is continuous). However, the egress capacity of lifts is in addition to that of the stairs. It is also worth noting that mobility-impaired people will be much slower on stairs, compared to lifts, and in very tall buildings, fatigue of stair users will become an issue.

Escalators

The number of escalators and their flow capacity should be noted, also the extent to which escalators are enclosed or pass directly through occupied areas of floors. As has already been discussed for stairs and lifts, there is a balance to be found between, on the one hand, achieving as rapid an evacuation as possible, and on the other hand, avoiding unnecessary exposure to smoke.

The way in which escalators can be managed and operated is also important. One option is for escalators to come to a halt when an alarm is sounded, when they could then be used like stairs. The difference with escalators is that the tread height is not optimised for climbing (leading to slower movement) and nor is it constant, which could form a trip hazard. Another option is for escalators to reverse direction, if appropriate, so as to carry people in the direction of the exit. This option obviously requires good communications and management, firstly to be aware of the incident location so as not to encourage people to head into danger, and secondly to stop people joining an escalator just before its direction is to be reversed.

One aspect where escalators are obviously different to stairs is if the alighting area is overcrowded. On stairs, it is possible for a queue to form while people are waiting to get off, but on an escalator, people will continue to be delivered to the alighting point. The risk of overcrowding is something that needs to be considered, particularly if it is desired to run some of the escalators in opposite directions to normal use.

Stairs/fatigue

People using stairs to evacuate may suffer from varying degrees of fatigue depending on a range of variables. In evaluating the potential emergency use of lifts or escalators for evacuation, it may be worthwhile assessing the potential impact of fatigue on vertical evacuation times. A fatigue model (FRS, c1978) may be adopted:

$$t_v(fatigue) = t_v + 1.8\left(\frac{t_v}{100}\right)^2 \quad (12)$$

where: t_v is the vertical movement time predicted using evacuation models that do not take fatigue into account.

This model was developed for staff evacuation of patients in hospitals. It has since been compared to real evacuations from underground train/tunnel events and high-rise offices (eg HSBC). The analysis also compares reasonably with the evacuation of the World Trade Center in 1993 [2].

Performance of vertical egress systems

Simple models such as that above can be used to indicate in broad terms the potential reduction in vertical movement time of using lifts or escalators for emergency evacuation.

Table B1 shows a summary of typical total evacuation times for different types of building. The buildings are code compliant with stairs sized for simultaneous evacuation (except for the high-rise offices). Pre-movement and movement times were predicted using PD 7974 Part 6 [8] and the capacity of lifts and escalators was evaluated using CIBSE Guide D [13]. For high-rise offices and hotels 12 storeys high or less, it was found that if 50% of occupants used the stairs and the other 50% of occupants chose to use the lifts, the overall evacuation time was increased (ie there was a negative benefit) whilst people waited for the lifts.

Table B2 shows the range of buildings and cases analysed. The table also shows the relative vertical flow rates of different means of evacuation. It shows the relatively low flow rate for stairs in buildings designed for phased evacuation and the relatively high flow capacity of lifts in these buildings. It is also clear that for buildings using simultaneous evacuation, the relative vertical flow capacity of lifts is small. Table B2 also shows the vertical movement times (with and without fatigue). This and other analysis indicates that the potential reduction in vertical movement time by using lifts and/or escalators for emergency evacuation is:

Table B1 Summary of evacuation times and benefits

Building	Number of storeys below which benefits are low (or negative)	Typical evacuation times for greater numbers of storeys (min)	Typical reductions in evacuation time (%)
High-rise offices	12	35 to 70	30 to 50
Underground station*	n/a	~12	~50
Shopping complex	n/a	~5	~20
High-rise hotels	12	25 to 40	5 to 35

Notes:
* Escalators are part of the evacuation standards for underground stations on the London Underground.

It should also be noted that the overall reduction in evacuation time (including pre-movement time) is likely to be lower than the reduction indicated, particularly where the movement time is low compared to the pre-movement time.

Table B2 Vertical evacuation movement capacities and times for simultaneous evacuation

Building	**Purpose Group**	**Case**	**Number of storeys**	**Vertical movement capacity (p/s)**				**Total vertical movement capacity (p/s)**	**Minimum vertical movement time[3] (min)**	**Minimum vertical movement time (with fatigue) (min)**
				Stairs	**Lifts**	**Escalator**	**Exit**			
High rise	Office	Stairs only (designed for phased)	16	2.0	0.0	0.0	0.0	2.0	25.2	32.0
High rise	Office	Stairs and lifts	16	2.0	0.8	0.0	0.0	2.8	17.8	21.2
Medium rise	Office	Stairs only	8	2.0	0.0	0.0	0.0	2.0	5.6	5.9
Medium rise	Office	Stairs and lifts	8	2.0	0.5	0.0	0.0	2.5	4.5	4.7
Underground	Station	Stairs and escalators1	2	3.7	0.0	4.0	0.0	7.7	6.1	6.5
Underground	Station	Stairs only	2	3.7	0.0	0.0	0.0	3.7	12.8	14.3
Complex2	Retail	Stairs and exits only	2	20.8	0.0	0.0	16.8	37.6	4.6	4.9
Complex	Retail	Escalators, lifts, stairs and exits	2	20.8	1.7	8.0	16.8	47.3	3.7	3.8
High rise	Hotel	Stairs only	16	3.3	0.0	0.0	0.0	3.3	8.1.	8.8
High rise	Hotel	Stairs and lifts	16	3.3	0.8	0.0	0.0	4.1	10.2	11.3
Super high rise	Residential	Stairs only	60	2.0	0.0	0.0	0.0	2.0	31.4	42.1
Super high rise	Residential	Stairs and lifts	60	2.0	0.6	0.0	0.0	2.6	23.8	29.9
Super high rise	Office	Stairs only	112	3.6	0.0	0.0	0.0	3.6	101.9	214.2
Super high rise	Office	Stairs and lifts	112	3.6	2.7	0.0	0.0	6.3	57.6	93.4

Notes:

[1] Some underground metro systems include using up escalators during evacuation as part of their evacuation strategy.

[2] This shopping complex included a wide horizontal walkway at one end of the site which had a major influence on the minimum movement times predicted.

[3] The minimum vertical movement time is based on optimum use of exit capacity by occupants.

Another useful way of assessing the potential benefits of the emergency use of lifts or escalators for evacuation is to plot the building on a graph of population against vertical movement rate (see Figure B1 below).

Figure B1 Population against vertical movement capacity

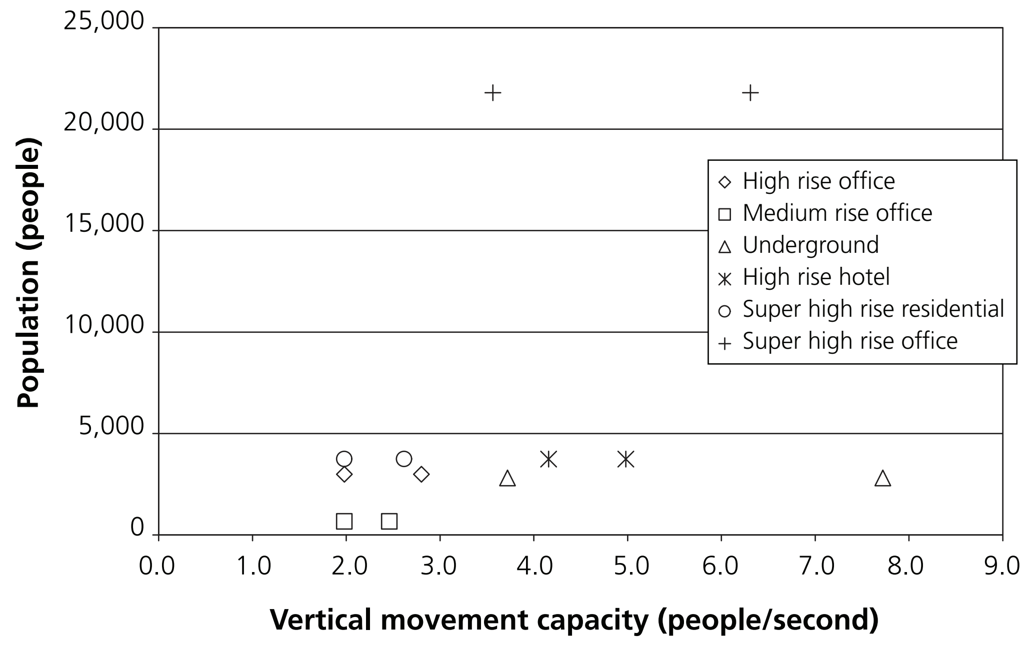


Figure B1 shows how different buildings vary in terms of population and vertical flow capacity. It shows that there are several types of building:

1. Low population/high vertical evacuation capacity, eg low-rise offices.
2. Higher population/high vertical evacuation capacity, eg underground stations and shopping centres (shopping centre vertical flow capacity was too high to show on this graph).
3. High population/low vertical flow capacity, eg high-rise/super high-rise offices.

Figure B2 Number of storeys against vertical movement capacity (for an office building)

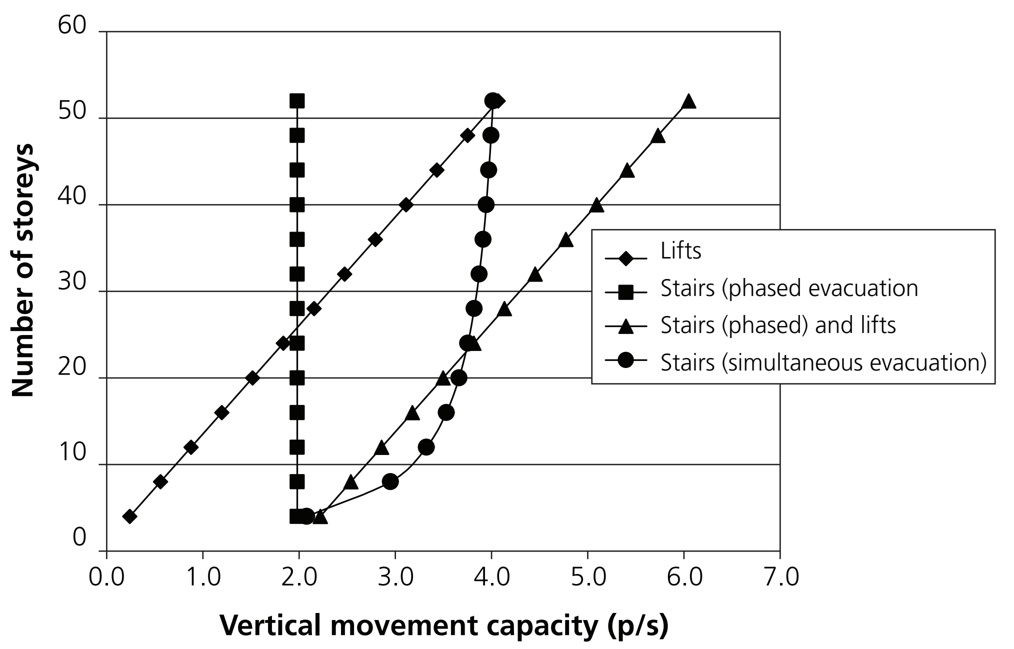


Figure B2 shows an example of the relative vertical movement capacity of stairs and lifts in a range of office buildings all with the same footprint. It shows the relatively high vertical movement capacity of stairs compared to lifts in low and medium rise office buildings. The relatively high vertical movement capacity of lifts in high-rise offices can also be seen along with the potential vertical movement capacity if lifts and stairs are combined.

Discussion

This Annex shows estimates of vertical movement times to illustrate where the greatest potential benefits are for the emergency use of lifts or escalators for evacuation. It should be noted that these estimates are illustrative and do not include:

- pre-movement
- horizontal evacuation
- evacuation of disabled or mobility impaired occupants
- individual characteristics
- stair, lift and escalator efficiencies (ie they are analysed as optimum/design capacity).

More complex evacuation modelling can provide confirmation of findings and/or further insight into the key variables (see Annex C).

Annex C

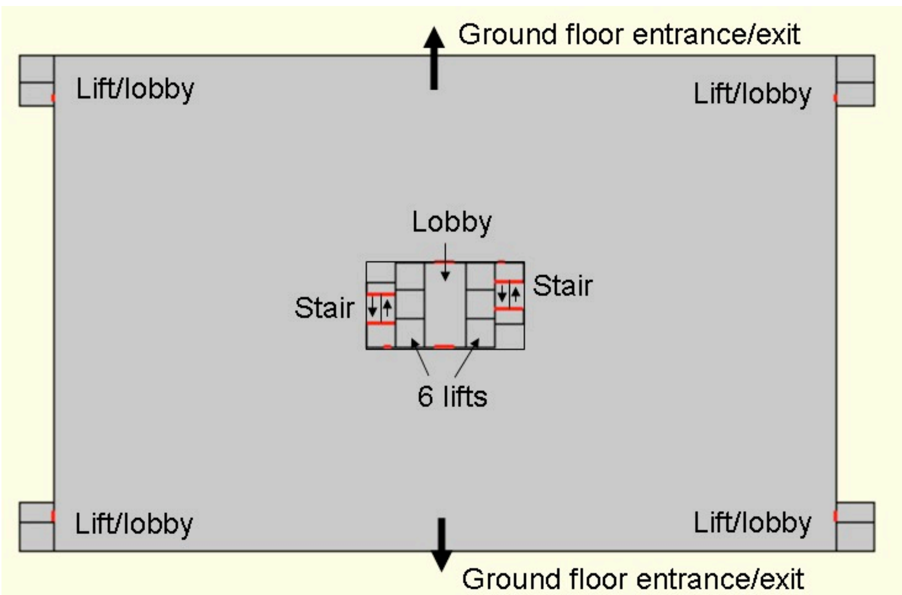
The use of discrete evacuation analysis

This Annex illustrates some of the insights that can be gained through discrete evacuation modelling. The example shown is a high-rise office and it is based on a building plan in NIST GCR-04-864-I [Klote 2004]. The building details are:

Number of floors	16
Length	57 m
Width	35 m
Floor area	1995 m^2
Floor to floor height	4 m
Lifts	6 cars in central core of the building
	1 car at each corner of the building
Stairs	2 stairs in central core of the building
Escalators	none

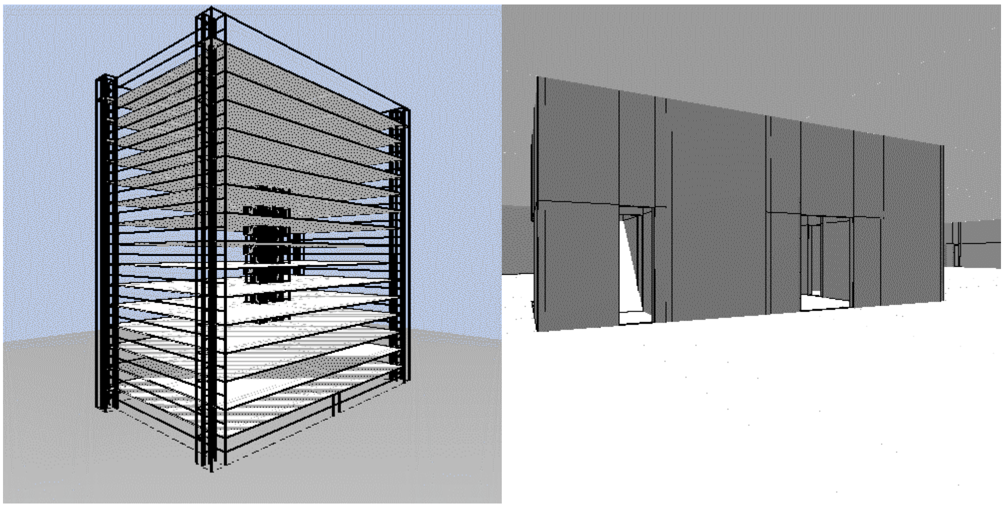
A plan of the building is shown in Figure C1.

Figure C1 Plan of high-rise building



The lifts at the corners are not intended to be used in addition to those in the central core but were provided to allow the simulations to examine the difference (if any) between people evacuating by all moving to the centre of the building or by dispersing to the corners of the building.

Figure C2 3D view of high-rise building and detail of central core



The CRISP model contains 240 spaces and 410 links.

Scenarios

Baseline scenario is:

Building population:	Based on 10 m^2/person 16 x 200 = 3200 people
Fire on the 8th floor	
Phased evacuation	[fire(8)], [9,10], [11,12],[13,14],[15,16],[6,7],[4,5],[2,3],[1] Phases are triggered at 150 s intervals
Lift rules :	Lift stops at the top floor that called it, goes to ground floor without further stops to pick up people, no restriction on who (eg people with disabilities) can use lift, runs at 80% capacity (ie a '10 person' lift is full with 8 people)

Only use lifts and stairs in the central core

A range of scenarios were modelled and some of the results can be seen below (Figures C3, C4 and C5).

The results of the analysis of two scenarios are shown in detail:

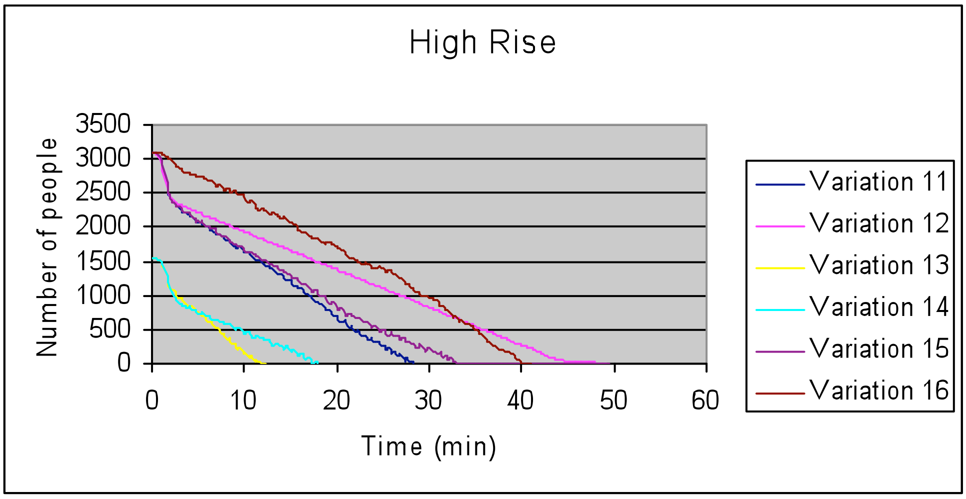
1. Phased evacuation by stairs only (Figure C6)
2. Phased evacuation where occupants could use lifts or stairs (Figure C7)

These are shown to illustrate the detailed insight this kind of analysis can provide to designers and/or building owners and operators.

Results

To illustrate the variation that can occur based on different evacuation scenarios, please see Figure C3.

Figure C3 Total number of people vs. time for scenarios (11-16)



Figures C4 and C5 illustrate how, for each scenario, graphs are presented for the number of people in each floor vs. time and for the height of the highest person originating in a given zone vs. time can be evaluated. This may be useful in terms of the distribution of people during an evacuation.

Figure C4 Total number of people vs. time

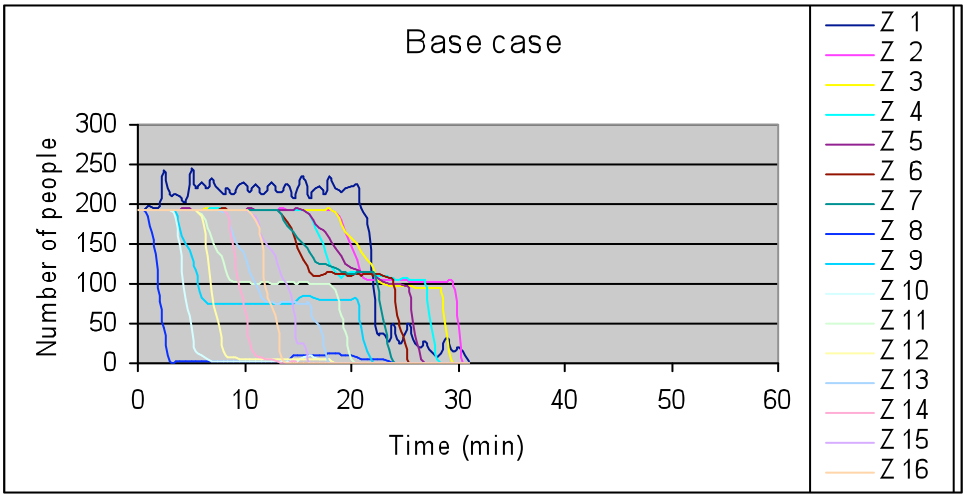
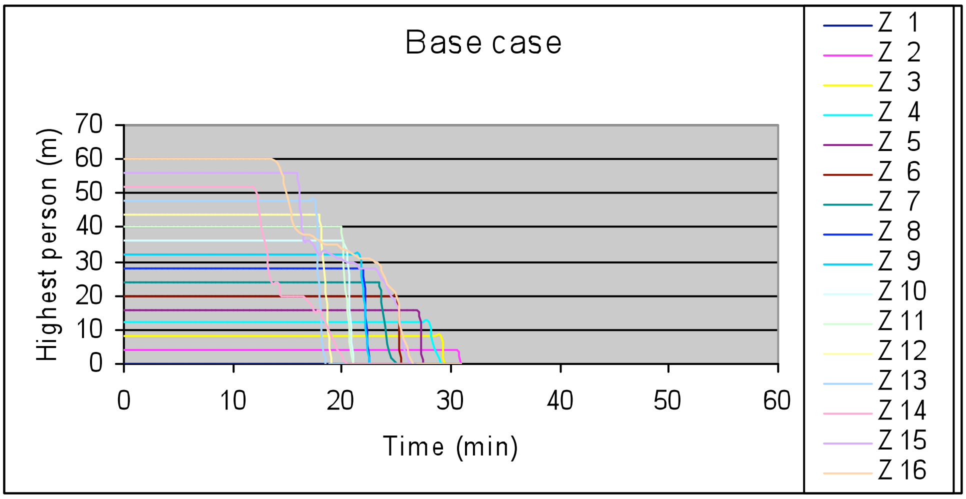


Figure C5 Height of highest person originating from each zone (floor) vs. time



The initial population of each zone and the time when each zone is cleared are shown in Table C1.

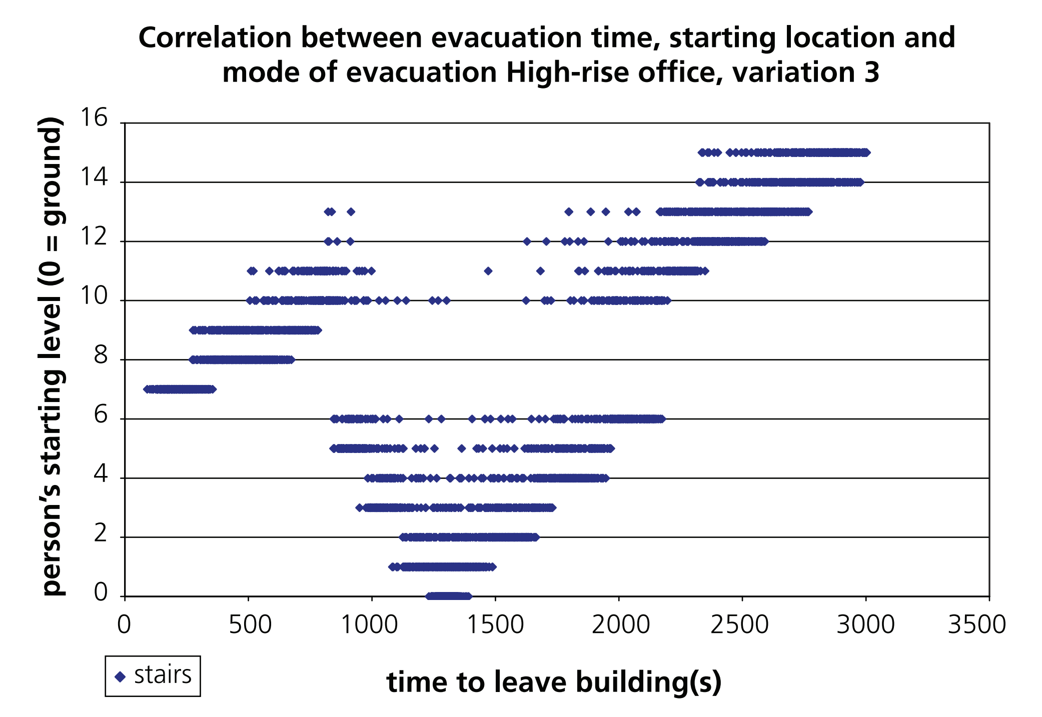
Table C1 Population and time to clear each zone

Zone	Initial population	Time cleared (min)	Zone	Initial population	Time cleared (min)
1	193	31.1	9	193	21.8
2	193	30.7	10	193	20.4
3	193	29.4	11	193	20.2
4	193	28.4	12	193	18.3
5	193	26.9	13	193	17.8
6	193	25.2	14	193	13.7
7	193	24.2	15	193	16.1
8	193	23.6	16	193	13.9

The following graphs show the starting location of a person, when they left the building and what type of vertical evacuation means they used.

Figure C6 shows phased evacuation using stairs only. Figure C7 shows phased evacuation of the same building using lifts and stairs.

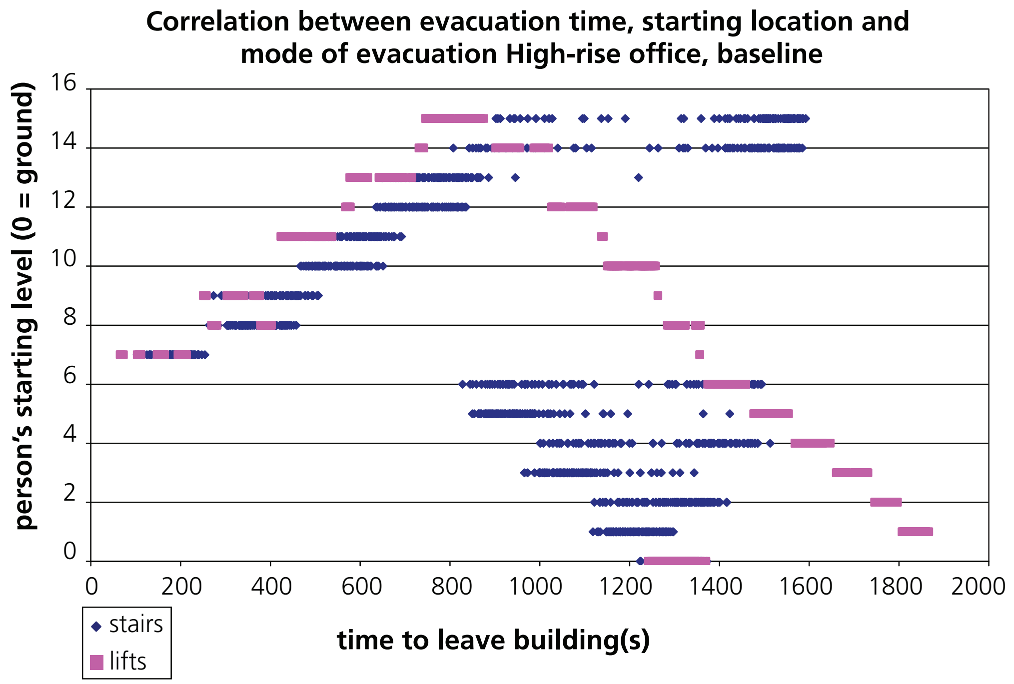
Figure C6 Correlation between the time each occupant leaves the building, their starting location (level), and whether they used stairs or lifts



In the case of Figure C6, lifts are not used, so the only option is to use the stairs in the central core. It is assumed that no people waste time attempting to use the lift; they all instantly choose the stair option. As the first phase involves only one floor (level 7), the initial evacuation is not impeded by the flow merging from lower floors. The second phase is affected to a slight degree. Note that the last people from floor 7 to leave the building do so after the first people from floors 8 and 9. The second phase also takes longer than the first simply because there are twice as many people involved.

The phase involving floors 5 and 6 commences at a time t=750s. The stairs above level 6 are all full of people evacuating from higher floors, who are all severely impeded by the need for the flow to merge at each level down. Once merging flows are established, the people from the lower floors will always manage to leave the building before those from higher floors.

Figure C7 Correlation between the time each occupant leaves the building, their starting location (level), and whether they used stairs or lifts



In Figure C7, the times to clear each zone do not follow the same order as the start times. Also, the first zone to clear is zone 14, 13.7 minutes after the evacuation starts. The reason for this is that each evacuation phase is given 2.5 minutes (150 s) before the next phase starts automatically. This is insufficient, and stragglers remain on each floor, thus leading to long times for clearance of each zone.

The graph showing the number of people v. time for each zone shows a number of interesting features. For the first zone to evacuate (Z7), only a few stragglers are left before the next phase starts. For the second phase (Z8 and Z9), there is a considerable disparity in the numbers of people evacuated – zone 9 is almost clear by the time the third phase starts, but zone 8 has a substantial number of people remaining. This is a consequence of the interaction (or lack of it) between the behaviour of the people and the lifts in our simulation.

The behaviour of the people is to make an initial choice of evacuation mode (stairs or lift) which they then stick to. Rather than attempting to predict how long people will wait for a lift before changing strategy, we force them to wait until a lift arrives, and then decide whether such a delay would be likely in reality.

The behaviour of the lifts is to go to the highest floor where people have called a lift. Furthermore, where there is a bank of lifts (as is the case for the six lifts in the central core), all the lifts will travel to the highest calling floor. The consequence of this is that, for each pair of floors being evacuated, lifts will not call at the lower of the two floors until there are no more people waiting to use a lift on the upper of the two floors.

Note that the number of people on the ground floor (Z1) fluctuates, and rises above the initial population – this is because people have to pass through the ground floor in order to get to the outside. The ground floor occupants are shown using lifts only because their escape route is through the entrance area of the building.

The correlation between starting location, evacuation mode, and each person's time to leave the building is rather complex at first sight. Firstly, let us consider the people who use stairs. For the initial phases of the evacuation, people are able to leave their floor and enter the stairs without being impeded by others. However, the fifth phase (levels 14 and 15) encounters problems, because by the time the stair users have walked down to the 6th floor, they become blocked by people leaving from the lower levels. This is a consequence of having fixed time intervals for each phase of the evacuation, rather than managing the process to ensure each phase is complete before the next one starts.

All the later phases are affected to a varying degree by blockages occurring when the next phase starts before the current phase is complete. The people on the stairs form a 'solid' queue, and we have assumed a 50:50 merging ratio for people joining the queue from a floor and people coming from the stairs above. Those people joining the stairs from a lower level are therefore much more likely to leave before those joining from a higher level.

For those people choosing to use lifts, there is insufficient time to evacuate everybody from the current phase, before the next phase starts. As the lifts give priority to the highest floor, this means there are always some stragglers waiting until their floor again gets priority. Once the top floor (15) has cleared, the lifts give priority to the next one below, in descending sequence. The lifts' requirement to clear people from floors 14, 13, … 7 means that, for people on floor 6, there is roughly a 10-minute delay (1400 s – 800 s = 600 s) between the first person to leave by a lift, compared to the first person out from floor 6 who chose the stairs.

Finally, it should be noted that people categorised as 'stair' or 'lift' users would be more accurately described as 'not lift' or 'not stair' respectively. For the people on level 0 (ground floor), their choice of 'stair_exit' or 'lift_exit' action makes no difference, since they can exit directly to the outside without having to avoid lifts or stairs respectively.

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