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Date 5 September, 2003

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## EXECUTIVE SUMMARY

The Building Control Commission has engaged a team, led by Lincolne Scott, to research the feasibility of using lifts for evacuation of people with disabilities.

The scope of this investigation has been limited to sprinkler protected office buildings. It is envisaged that office buildings will provide a good starting point for other classes of buildings which can be considered at a later stage.

The study is comprised of two main parts. The first part is a literature survey to summarise the finding of previous studies into this area. The second part postulates a design solution which is expected to meet the requirements of the Disability Discrimination Act while limiting the augmentation to current Building Codes and Standards.

The most salient point of the literature survey has been that building occupants are not subjected to a high fire risk in sprinkler protected buildings. Subsequently the requirements for fire compartmentation and structural durability within a floor of a building are satisfied by the presence of a sprinkler system. However, the propagation of smoke through the building is still considered a danger which must be addressed. The other key point of the literature survey is that little reliable research has been published on the topic of people with disabilities evacuating from multi-level buildings and of lift performance under fire conditions.

A possible design solution has been developed and analysed by both fire engineering and full scale fire testing. This solution relies on the following items to provide a safe outcome:

- a) People with disabilities utilise the lifts to evacuate from a building in an emergency.
- b) Use of a lift lobby to maintain tenable conditions while people with disabilities wait for a lift to arrive. The lobby may be of lightweight construction but requires a positive pressure difference between the lobby and the surrounding space. The design does not include special purpose single usage places of refuge.
- c) Minor design changes to the controls and management of the lifts to increase their level of efficacy and reliability in an evacuation.
- d) Modifications to the structure and services surrounding the lift, including the two main threats to a lift in a fire which are smoke from the fire and water from the suppression systems are suggested.
- e) Introduction of more specific regulations governing the management of a building which deals with all people in an emergency situation. Also, maintenance of both the built systems and people systems must be regularly verified.

The implementation of the above solution is expected to have only a minor impact on the capital expenditure for new buildings and contain costs within acceptable limits to establish compliance of existing buildings.

It is recommended that further investigation be performed into how people with disabilities react in a fire and how a fire scenario affects their movement.

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# 1. INTRODUCTION

Over the past few years much attention has been given to the needs of people with disabilities. In particular the introduction of the Disability Discrimination Act, 1992 (DDA) has had a marked effect across many industries. The Building Industry and the owners and managers of buildings are no exception. Many people are conscious and willing to meet the requirements of the DDA but unsure exactly what is required. This stems from the fact that the DDA does not have a "compliance standard" or the like which sets out the requirements of building owners and/or designers. Presently, the Act can only be tested after the event, by litigation and complaint, to ascertain what constitutes a breach.

In order that building owners can meet these needs with more certainty, the Australian Building Codes Board (ABCB) has instigated and led a detailed public discussion and review process. The objective of this review is to introduce into the Building Code of Australia (BCA), measures which can be relied upon to meet the requirements of people with disabilities and to achieve compliance with the DDA.

One key topic addressed has been the matter of equity of egress for people with disabilities. This wide ranging review has included previously held views that in many buildings, safe areas of refuge may be required. Current building regulations already recognise the need to use lifts for evacuating people with illness, injury or disabilities, and requires emergency lifts with stretcher capacity to be provided in buildings exceeding specified heights.

## 1.1 OBJECTIVES

The objective of this study is to research the feasibility of using lifts for evacuation under a fire emergency and to recommend what modifications to building design or operation might be needed to achieve an effective outcome under these circumstances. The feasibility of the design will be tested against safety of occupants achieved. The level of capital cost required to achieve the result will be assessed.

Change to the existing regulations, codes, and standards necessary to achieve suitable performance can then be identified. Such changes can provide building owners and designers with a "deemed-to-satisfy" solution for providing facilities to evacuate people with disabilities in an emergency. Such changes can provide compliance with the DDA and safety for people with disabilities can be achieved. This allows more certainty for designers and comfort for building owners provided BCA compliance establishes an accepted compliance with the DDA.

## 1.2 STUDY METHODOLOGY

As the question of egress for those with disabilities has been a highly contentious topic for some time, there have been many previous investigations into evacuation of people with disabilities. The use of lifts for evacuation of people in general has also been researched. Therefore, a literature review of previous studies has been undertaken to consolidate previous findings and recommendations.

The results from the literature review has been taken into account to formulate a possible building design solution. The intention of this solution is to provide safe evacuation conditions for people with disabilities. Such a solution should be reliable, cost effective, and in line with current design practices where possible.

A questionnaire, distributed to local building owners/managers, is used to assess current management practices. Also information on occupancy levels in high rise office buildings and populations of people with disabilities has been gathered to formulate a basis for design.

In order to test the postulated building design solution and thus the means of providing egress using lifts, a fire engineering analysis to assess the likely outcomes has been undertaken. A performance based approach is necessary as no "deem-to-satisfy" provision currently exists as highlighted by the topic of this study. The assessment of the trial design has involved reference to previous experimental and analytical work, expert judgement, computer analysis and full scale fire testing of a typical lift lobby.

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A second questionnaire has been distributed to lift manufactures to assess the feasibility of implementing the trial design and what the cost impact the changes in such a design would have.

The trial design solution is then referenced to the relevant Codes and Standards to identify the likely need for change if it was adopted to form a Compliance Code for the DDA via amendment of the BCA.

### **1.3 REPORT OVERVIEW**

The basic objective of safe building design is to provide for people to be able to evacuate a fire affected area before the conditions become untenable. Thus, the first goal of the analysis is to establish how long it takes to evacuate a typical office space. The response time, to commence the evacuation, depends on the nature of the message to occupants and their ability to interpret and act. The travel time of occupants depends on three main variables: how many people need to evacuate, what are the characteristics of the people, and the means by which they evacuate (eg travel distance, use of stairs/lifts, etc.). Section 3 addresses the number of people and their characteristics.

Currently all occupants are expected to use stairs to evacuate the building in an emergency. However, this can be a very lengthy process especially when people with disabilities are involved who are unable to use stairs unaided. Section 4 addresses the potential effectiveness of using lifts to evacuate occupants.

Once the variables which govern movement times are defined, the factors which influence the time to untenability are addressed. These factors are based on what potential for fire exists in an office building and what systems are in place to limit the effects of the fire on tenability. Section 5 covers analysis of the likely fire scenarios in office buildings. Sections 6 and 7 address both the built structure and services and building management systems respectively.

### **1.4 LIMITATIONS**

The scope of this investigation has been limited to Class 5 (office) buildings as defined by the BCA. Buildings considered are over 25m in effective height and sprinkler protected. It is envisaged that office buildings will provide a good starting point for other classes of buildings which can be considered at a later stage.

The study primarily addresses the physical aspects of buildings and the physical consequences of fire. Simulation of building management systems has not been undertaken.

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## 2. LITERATURE REVIEW

A listing of relevant literature is included in Appendix 1. This bibliography has been used in the study.

### 2.1 DISABLED EGRESS

There are currently many publications which address the requirements of access for people with disabilities. As people have been aware of these issues for some time, many of the access requirements have already been addressed in the BCA or the Australian Standards referenced therein.

However, the literature is not as comprehensive when it comes to the evacuation of people with disabilities. Much of the available literature makes reference to the use of “refuges”. The general concept of these areas is that they are purpose built such that people are able to be directed into the refuge and be able to wait until the fire threat has finished or the Fire Services assist the people out of the refuge and out of the building. Such a solution assumes much in regard to the level of effective communication under emergency conditions and management protocols adopted.

The assumed benefit of a refuge is that, if properly designed, it may provide a safe place within the building to wait until safe evacuation is available. However, there are also several drawbacks to the concept of a refuge. Firstly, it requires occupants with disabilities to wait within the building while all other occupants evacuate which contravenes the equality clause of the DDA. Secondly, as they are essentially to be a fire safe box they must have no fire load within them. Therefore they become unusable space during normal operation of the building. The designer will have to sacrifice useable area which will ultimately be costly. Thirdly, since refuges are not used as part of people’s regular occupation routine, they are an unfamiliar place within the building and not the natural instinctive area to go in an emergency. This has the potential for making them unreliable as occupants may not be aware of the existence of the refuge particularly if they are a visitor to the building. Utilising refuges as a solution imposes significant burdens on space consumed and emergency management resources. If they are not normally in use, the reliability of availability ( they represent a likely storage space ) and support services is open to question. Adoption of normally occupied but ‘fire sterile’ spaces such as toilets as refuges is possible but not without problems of access and space consumed.

Perhaps most importantly, adoption of a building solution which is significantly reliant on the intervention of Emergency Services personally will necessitate having a set of operating procedures in place, on which occupants can rely.

Such procedures are not presently evident. If they exist they are not widely circulate.

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## 2.2 FIRE SCENARIOS

A number of publications purport to deal with the issues of “refuges” and evacuation of occupants by lifts. Ref [1] considers the use of lifts for the evacuation of staff from air traffic control towers. The second Symposium on Elevators, Fire, and Accessibility was held in Baltimore, Maryland in 1995 [2] and covered a wide range of topics including the operation of lifts under fire conditions, smoke management, the evacuation of occupants (including those with mobility disabilities), and a whole series of equipment issues. As might be expected, the above matters are discussed from various perspectives. These papers present both concerns and opportunities with respect to the use of lifts for the evacuation of occupants using lifts. Issues raised include:

- i. The natural “aversion” of emergency services personnel, building occupants and staff to using lifts during a fire emergency
- ii. The possible effect of water from activated sprinkler heads on lift car operation
- iii. The possible effect of water from hose lines on lift car operation
- iv. Failure of lifts due to heat from a fire
- v. Need for effective servicing of lifts to achieve reliable operation
- vi. People may succumb to the effects of a fire while waiting for a lift
- vii. Panic associated with overcrowding of lifts - doors will not close
- viii. Doors may not close due to friction created by differential pressures generated by fire.
- ix. The possibility of power failure to lifts during a fire emergency
- x. Smoke control for elevator lobbies and shafts needs to be considered.

Some Authors consider the use of elevators (lifts) for the evacuation of all occupants rather than only those people with disabilities. Direct consideration of this issue is beyond the scope of this report although the studies include an assessment of likely performance under this duty. This issue raises some significant matters with respect to fire time-lines and lift capacity compared to population in addition to those listed above.

Many of the Authors assume that evacuation of occupants by emergency stairs will be safer than using the lifts. There appears to be little questioning of the likely tenability of the stairs in the event of a significant fire. In fact, the tenability of the stairs will be a function of the size of the fire (whether the building is sprinkler protected or not), the state of the fire doors (the effect of maintenance or lack of it), whether the emergency stairs smoke exclusion systems exist and operate (are pressurised) successfully and the evacuation management regime. In the event of a major non-sprinklered fire, untenable conditions may occur within the stairs within a relatively short time, depending on the factors noted above.

The issues raised above (i. - x.) are now briefly considered.

The aversion to the use of lifts during a fire can be considered to be a product of years of education and conditioning. Considering the needs and capacities of people with disabilities demands a serious reconsideration of prior assumptions as to the effectiveness of stairs as an evacuation route.

The impact of water on lift car operation is a significant issue. However, consideration of this issue must take into account the likely quantities of water associated with a sprinklered fire, the location of the lift controls, and the duration required for lift operation to provide evacuation. These issues have been addressed elsewhere in this report.

In the case of a sprinklered fire, the heat and associated pressures are expected to be insufficient to impact on either lift controls or effectiveness of door opening. It is important that lifts are effectively maintained as this is important from a building function aspect and, in any case, from a public health and safety viewpoint. This matter is considered in greater detail in Section 7 which addresses building management.



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The possibility that people may succumb to the effects of a fire, whether inside or outside the lift, is a real one and is addressed at some length in this report. However, the possibility of panic associated with inadequate lift capacity is very unlikely in a sprinklered building due to the fact that generally only small numbers of people will need evacuation and multiple lifts are provided in most buildings.

The issue of possible power failure during a fire is an important one but is unlikely to be an issue in a sprinklered building provided there is adequate protection of critical electrical cabling from the effects of water and that emergency services standard operational procedures do not lead to premature disablement of the lifts. The likelihood of an external power failure and a building fire occurring at the same time is extremely low. Consideration of events which have the potential to have these happening simultaneously (eg, earthquakes) is beyond the scope of this report. Again, this is addressed elsewhere in this report.

The possible presence of smoke within the lift shaft is an issue which is also dealt with to the extent that provided the area adjacent to the lift doors (lobby) is kept clear of smoke, penetration into the shafts is unlikely. This is considered further in Section 4.

Nelson [3] presents the results of an investigation into the tenability of buildings and refuges. A number of buildings were considered including sprinklered and non-sprinklered situations. The paper appears to be an evaluation of areas of refuge which are located adjacent to the lift shafts. The conditions within the critical parts of the building are evaluated - the areas of refuge and the corridor leading to the area of refuge.

The tenability of the various areas are theoretically evaluated using a series of NIST programs with assumed fire characteristics as defined by the rate of heat release of the fire. No experimental data is presented in support of the theoretical calculations. However, it is concluded that without sprinklers, occupants in both the corridor and refuge area may be overwhelmed by smoke. The provision of sprinklers will maintain sufficient tenability within the corridor and that the smoke conditions arising from a sprinkler controlled fire are insufficiently severe to threaten life. Sprinkler protection provides a superior level of safety compared to the provision of refuges.

## 2.3 LIFT USE AND RELIABILITY

Many of the published papers relating to the use of lifts in fire emergencies look for advanced technology and complex systems to deal with the impact of fire and the effects of fire suppression systems on lift operation.

A number of papers presented at the ASME International 2<sup>nd</sup> Symposium (Ref 2) refer to the probability of being able to design systems to withstand heat, smoke and water, but few of these authors look at the practical aspects of the implementation and long term maintenance of such approaches.

In his paper "Fire and Elevators - The Building Environment", Strakosch (Ref 16) puts into a practical context, the shortcomings of many of the theoretical approaches suggested. In particular, Strakosch makes mention of the need for a complete building system approach to providing safe means of egress for people with disabilities (and others).

Included in Strakosch's recommendations are references to the need to keep high-tech solutions simple so that they will be useful in a wide range of circumstances and to the fact that chosen protection systems must remain workable over the life of the equipment and the building.

The Lift Code in New Zealand (NZS 4332) **requires** lifts to be recalled automatically but in response to an over temperature condition in the Lift Motor Room (LMR). Whilst the intent of this Australasian Standard is considered reasonable, the effect of the recall requirement is to render the lifts inoperable.

Acceptance in codes in Australasia and elsewhere of the automated recall concept for lifts is noted. However, the method and purpose of such recalling of lifts must be directed towards a planned response. These are discussed in detail in a later sections.

## 2.4 MANAGEMENT UNDER EMERGENCY CONDITIONS

Relevant literature in regard to management under emergency conditions includes :

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- SAA MP24-1972 Use of lifts in Emergencies
  - AS 3745 –1995 :Emergency control organization and procedures for buildings

SAA MP 24 was written by the then committee on Lift Installations and reflects the then current view of the world. None the less It contemplates a solution of protecting lifts by lobbies, with such lobbies providing a relatively safe area of temporary refuge.

A review of SAA MP24 indicates that the design tested for feasibility addresses many of the issues raised. SAA MP24 provides some insight into management issues under emergency conditions, but is inconclusive as to providing actual guidance of a suitable regime.

AS 3745 covers general management structures, responsibilities and actions . It contemplates fire, bomb threat and civil disorder as sources of threat requiring emergency management.

It contemplates the use of a range of evacuation routes, but assumes that lifts should not be used except for the evacuation of people with disabilities “under the control of the combating authority”. This has the consequence of the management of evacuation of people with disabilities being delayed until such authority arrives.

AS 3745 does not contemplate sources of information beyond the systems covered by AS 2220, nor does it address demarcation of responsibility between the building ECO ( Emergency Control Organization ) and any external agency who might have emergency management control powers vested in them under the relevant legislation .

If Lifts were to be used for evacuation of people with disabilities, some amplification of the framework provided by AS 3745 would be required.

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## 3. OCCUPANCY IN CLASS 5 BUILDINGS

### 3.1 OCCUPANCY LEVELS

The current BCA suggests that office buildings have an occupancy level of 1 person/10m<sup>2</sup>. This value in the BCA is used to calculate the required egress width.

The Australian Standard AS 1668.2 (Mechanical Ventilation for acceptable indoor air-quality) also suggests using 1 person/10 m<sup>2</sup> for general office areas.

For comparison the replies to the building manager questionnaire indicated the average occupancy level was 1 person/19m<sup>2</sup> (with the minimum 1/9m<sup>2</sup> and the maximum at 1/39m<sup>2</sup>). Thus, the value used in the BCA seem to be within the correct order of magnitude but over estimates actual occupancy levels.

Experience gained undertaking design and documentation of some 500,000m<sup>2</sup> of tenancy fitout work indicates a value of 1/15m<sup>2</sup> although some organisations are now actively working to reduce this ratio.

Denser populations than this value are seen as highly unlikely, particularly if net lettable areas are used. Conservatism increases if gross floor areas are used in analysis and design calculations.

Actual occupancy levels are generally less than design levels due to people attending to business outside the office, annual leave and sick leave. Annual leave and sick leave alone are likely to result in a 15% reduction in density. Work practices and the nature of business conducted can reduce actual occupancy rates to some 50% of the number of work stations or seats provided.

Using 1/10m<sup>2</sup> would result is a very conservative value for use in assessment of office buildings. It could easily be twice the actual value of normal occupancy patterns but allows for intermittent attendances for occupancies serving the visiting public .

A percentage of people on a typical office floor can be expected to have a disability. However, it is difficult to define a fixed number as it fluctuates markedly between buildings, businesses and times of day. The following statistics on both the general population and the population of people with disabilities within the work force provide a perspective that a design population of people with disabilities can be based upon.

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## 3.2 DISABLED OCCUPANT STATISTICS

### 3.2.1 Key Definitions

In order to correctly discuss the numbers of people with disabilities, a few key terms have been defined below:

#### Disabling Condition

A disabling condition is any condition which had lasted or was likely to last for 6 months or more and resulted in one or more of the limitations, restrictions or impairments listed below:

- ⇒ loss of sight (even when wearing glasses or contact lenses);
- ⇒ loss of hearing;
- ⇒ speech difficulties in native languages;
- ⇒ blackouts, fits, or loss of consciousness;
- ⇒ slowness at learning or understanding;
- ⇒ incomplete use of arms or finger;
- ⇒ difficulty gripping or holding small objects;
- ⇒ incomplete use of feet or legs;
- ⇒ treatment for nerves or an emotional conditions;
- ⇒ restrictions in physical activities or in doing physical work;
- ⇒ disfigurement or deformity;
- ⇒ head injury, stroke or any other brain damage;
- ⇒ a mental illness requiring help or supervision;
- ⇒ treatment or medication for long-term condition or ailment;
- ⇒ any other long-term condition;

#### Disability

In the context of health experience, a disability is any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered “normal” for a human being.

#### Handicap

A handicap is identified as a limitation to perform certain tasks associated with daily living. The limitation must be due to the disability and in relation to one or more of the areas listed below:

- ⇒ Self-care – difficulties in showering, bathing, dressing, eating, toileting, bladder or bowel control;
- ⇒ Mobility (profound/severe/moderate) – difficulties in going places away from the home/establishment, moving about the home/establishment, transferring to and from a bed or a chair.
- ⇒ Mobility (mild) – limitation in walking 200 meters, walking up and down stairs or using public transport.
- ⇒ Verbal communication – difficulties understanding or being understood by strangers/family/friends/staff/ in the person’s native language;
- ⇒ Schooling – limited in the ability to attend school or needing to attend a special school or special classes
- ⇒ Employment – limited in the ability to work, the type of work performed and other work problems such as the amount of time off required and special arrangements which need to be made.

### 3.2.2 Statistics

#### Overview

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In 1993, it was estimated that 18% (3,176,700) of the population within Australia had a disability however 78.7% (2,500,200) of the 3,176,700 were classified as having a handicap.

Unfortunately many of the people classified as having handicap are limited by the physical environs not their disability.

Of the 2,500,200 persons with a handicap, the most frequently reported area of handicap was mobility where 1,827,500 or 73.1% reported mobility limitations. The next most frequent reported area of handicap was employment where 1,497,900 or 60% of persons with a handicap reported employment limitations.

### **General Statistics**

- 336,500 people use sticks, walking frames or crutches (approximately 2% of the community)
- 84,000 people use wheelchairs or scooters (approximately 0.5% of the community)
- 8,400 use artificial limbs (approximately 0.05% of the community)
- 9,000 people use callipers or splints (approximately 0.05% of the community)
- 259,500 people use hearing aides (approximately 1.5% of the community)
- 47,300 people use telephone adaptations (approximately 0.25% of the community)

*Percentages are based on the Australian community and a population of approximately 17 million people.*

### **General Disability Statistics**

- 7.4 percent of people between 15 and 25 years have a disability
- 11 percent of people aged between 35 and 45 years have a disability
- 36 percent of people aged between 60 and 64 have a disability

### **3.2.3 Employment Statistics of People with a Disability**

Bearing the above numbers in mind, along with the general statistic that 18% of the community have a disability the following can be applied.

- Between 4% and 8% of the work force have a disability. Of the people with a disability in the work force, it is expected that a significant number of people with disabilities will be engaged in office type work, as distinct from occupations requiring physical work to be undertaken.
- The majority of the people with disabilities in the work force have mobility impairments
- Wheelchair users are not a high percentage of people with disabilities who are in employment
- The amount of assistance a person with a disability will require to evacuate a building will vary from nil to significant
- Such assistance will also depend upon the nature of the egress path of travel from work areas and the provision of an appropriate emergency management plan.

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### **3.3 DESIGN POPULATIONS**

As can be seen above there are many classes of disabilities all which must be taken into account when assessing the ability of people with disabilities to evacuate. This report addresses two main areas of disability classification. The major area is those people who have mobility impairments due to their physical characteristics (including the visually impaired). These people are likely to have difficulty in using the stairs to evacuate and thus are the primary candidates to use lifts to evacuate.

Secondly, although to a lesser depth, this study also addresses people who are hearing impaired and require to be informed of an emergency by means other than an audible tone or message.

The other key statistical outcome is that while the general population has an occurrence of people with disabilities of 18%, the percentage in the work force is much lower. While it is conceivable that particular scenarios may have a larger concentration of people with disabilities, an upper mean value, considered appropriate to the design and management of office buildings, is 6% of the overall office population. In the event where the population of people with disability is greater than the 6% additional measures may be required to ensure safety.

It is noteworthy that only a portion of the 6% will be mobility or audibly impaired and that building solutions relying solely on physical planning and building systems, as distinct from those embracing an effective management plan, are less likely to be efficacious. Such plans are contemplated by the DDA and have relevance in the context of establishing safe egress.

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## 4. LIFTS

### 4.1 EXISTING PRACTICES & LIFT SYSTEM CAPABILITIES

The existing regulated requirements and practises associated with the provision of lift services for use during a fire situation *in buildings with an effective height of over 25m*, comprise the following.

#### 4.1.1 BCA Requirements for Lifts (as at Amendment 5)

Access for people with disabilities	Every passenger lift serving a storey required to have access for people with disabilities (see D3.3) must meet the requirements of E3.6, which sets down minimum sizes of lift and facilities to be provided, including handrail, control button locations, and door protection devices.
Stretcher Facility	Each storey must be served by an emergency lift having a stretcher facility. (Each storey could be served by a different lift). BCA Clause E3.2.
Emergency lifts	Each storey must be served by one emergency lift, where only a single passenger lift serves that storey.  Each storey must be served by two emergency lifts, where two or more passenger lifts serve that storey.  If the passenger lifts serving a storey are in separate shafts, at least one lift in each separate shaft serving that storey must be an emergency lift.
Fire Service Controls	All passenger lifts are required to have fire service controls as defined by AS1735.2
"Do not use lifts ...." signs	All lifts are required to have a 'warning' sign at each landing, alerting lift users not to use the lifts if there is a fire (in the building). BCA Clause E3.3.

Reference to current BCA requirements may have the potential to mislead as to the real situation, where many buildings and their lift installations were completed prior to the existence of the BCA. Whilst a benchmark for analysis of expected building performance is necessary for a study of this nature, and use of buildings meeting present requirements is an appropriate basis for analysis. A desirable outcome would be that building solutions providing appropriate performance could be achieved with efficacy for the majority of existing installations without major upgrades to the other services in the building to meet current regulations and standards.

#### 4.1.2 Other Relevant Codes and Regulations

Most lifts in Australia are subject, in one way or another, to a regulatory regime having its basis in 'Occupational Health and Safety'. Whilst the aspects of lift performance relating to passenger safety are generally captured under these provisions, the existence of two potentially different regulatory regimes, 'Building Control' and 'Lift Inspectorates' can lead to a range of outcomes, with the potential for inflexibility and resistance to change. Achievement of building solutions aimed at providing effective access and egress using lifts will need to address this issue.

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In other codes and regulations (and within general good engineering practices) there are provisions which are intended to prolong the operational integrity of lifts in the event of fire. Generally, these apply to all lifts, not just emergency lifts, and include such matters as:

- Electrical supplies to lifts are connected to the live side of the building's main switch. It would appear that this is provided so that if Fire Service personnel elect to switch off general electrical supplies to the building, lifts can be left operating, thus not inadvertently trapping passengers in lifts at the time supply would otherwise be switched off.
- The wiring system used to provide electrical supply to lifts is required to be carried out in fire protected cabling from the point of supply to the lift machine room. Some mechanical protection requirements are also now included for such cabling. (Ref. AS/NZ 3013 – WS52)
- Sprinkler protection systems associated with lift equipment are required to be dry/alarm head type in lift machine rooms (to avoid water damage to a whole group of lift controllers); and conventional wet head type within lift shafts. This latter issue would appear to be inconsistent with the risk of accidental discharge – see later.
- In some states there is a requirement for a dedicated fireman's intercom system to be fitted in the lift car, lift machine room and at the main lobby floor. In some jurisdictions, this intercom system is integrated with the "Brigade" intercom installed in the building.

The 'double jeopardy' in design, construction and operation arising from having parallel regulatory regimes could be resolved by consolidation of the public safety requirements into the building regulations.

#### **4.1.3 Lift System Capacity**

As a result of market expectations and industry norms, lift systems in non residential (office) buildings are generally designed for a five minute 'handling capacity' of between 10% and 15% of the building's total expected population, which is normally predicted on the basis of the available net area of the floor space. This is one of the primary design bases used for the selection of the number, size and speed of the lifts serving a particular section of the building. Whilst methods of calculation vary from one designer or manufacturer to the next, the results are generally fairly consistent and are used as a means of comparison of lift capacity from one building to another.

As lift performance, insofar as the quality of service delivered, is regulated only by market expectations, the design population used for estimating lift performance is often different to that utilised under the BCA for the estimation of egress and other issues.

For lift system design, there is no mandatory basis for estimating population and market forces prevail, to the extent that claimed lift performance in regard to 'handling capacity' can be based on population densities as widely apart as 1/12m<sup>2</sup> to 1/16m<sup>2</sup> on the basis that these densities are reflective of actual occupancy (see 3.1 above). For consistency a population of 1/10m<sup>2</sup> has been used in the studies undertaken in the course of this work. This basis is highly conservative as noted previously.

If a passenger lift group is designed for 11% 'handling capacity', then it is theoretically capable of filling or emptying the building's design population in approximately 46 minutes. At a design capacity of 15%, a figure often used in more prestigious buildings, the design population for the whole building population can theoretically be moved in around 35 minutes.

In a typical class 5 building with an effective height over 25m, there is usually more than one lift, and lifts are grouped so that each floor is served by a bank of between 2 and 6 lifts (but at times up to 8 lifts in one group). Where a building has more than 14 to 16 floors above ground, the lifts are usually split into vertical rises of two or more. In a building of 40+ floors, three or four vertical rises are common. For reasons of efficacy and design logistics, all lifts serving a floor are grouped into the one location (core), in close proximity to at least one stair and entries into tenancies.



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Market expectations for lift performance in office buildings will usually dictate that on average, one lift is provided for every 2,800m<sup>2</sup> to 3,400m<sup>2</sup> of net rentable area, depending on the quality and height of the building. Similarly, the lobby space on each floor is based on commercial expectations that result in there being sufficient area in the lift lobby for people to congregate comfortably whilst waiting for lift service, and to allow traffic to flow through the lobby without interfering with waiting lift users. In general, this results in minimum dimensions of lift lobby areas that comfortably accommodate the population of people with disabilities plus a 'buddy' or 'helper' under emergency conditions.

Thus, it can be expected that, in all normal circumstances, the design process for a functional office building will result in the lifts being the central focus for entry and exit to any floor of the building. Furthermore, the number of lifts and the size of lift lobby at any typical floor will be commensurate with the size of floor they serve and thus the number of people on that floor. In tall buildings with more than one rise of lifts, these factors will also be applicable in a vertically segmented manner, in that the lobbies for low and high rises will be similar to each other in plan, but separated in a vertical sense.

The net effect of the foregoing is that, normal market expectations are expected to result in lift waiting areas (or lobbies where they are enclosed) which are capable of serving the needs of people with disabilities in egressing the building. Prescription of such facilities is not expected to be necessary.

The actual times to fill or empty a building or a particular section will vary in practice and can be dependent on individual factors such as lobby layout and lift control system algorithm. Broadly speaking however, very few buildings would be designed for a 'handling capacity' much in excess of 15%. Thus it would be reasonable to assume that the shortest time likely to be experienced when trying to empty a complete building quickly, such as might occur during an evacuation, would be of the order of 35 to 40 minutes. This assumes that the lifts are used in an orderly manner, left to operate on fully automatic control, and are all available for service at the time of the evacuation. It is unlikely that manual control of the lifts would enable the rate to be improved, unless the lift operators were specifically trained for the purpose.

Focussing the capacity of lifts in a bank on a single floor can result in much shorter evacuation times for that floor.

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#### 4.1.4 Existing Lift Operation Under Fire Conditions

The basic characteristics of an emergency lift as required by the BCA, are for a lift system that:

- serves floors as required by BCA E3.4;
- has lifts with a minimum rated load of 600kg (if the effective height of the building is over 75m);
- has fire services controls as called up in AS1735.2. (the BCA specifically refers to AS1735.2, which by itself is not a mandatory standard in all states of Australia);
- shafts containing required emergency lifts are to be separated from one another.

The nature of these requirements are operational and capacity related. There are no rules requiring an emergency lift to be inherently more fire safe in a physical sense, than other lifts in the building. The requirements for the electrical supply to the lift, protection or separation of the emergency lift shaft from other lifts or parts of the building, and fire rating of the lift well enclosure and doors, etc, are the same as those for other lifts. In general practice, an emergency lift is the same as other lifts in the building, given that all lifts are required to be fitted with fire service control (the principal requirement of an emergency lift).

The fire service controls referred to in AS1735.2, have as their main requirements; a recall switch at the main lobby to return all lifts on an express basis to that level; and, a switch inside each lift car to allow each lift to be manually controlled in a manner suitable for cautiously approaching a fire (destination floors can be selected, changed and cancelled by the operator, doors are under manual control, and door protection devices are not operational).

The method of recall is usually arranged on a lift rise by lift rise basis, ie. all of the Low rise lifts in one group, all of the High rise in a separate group, etc. Main lobby recall is not permitted to be initiated automatically, it must be manually switched, usually by the Fire Service. When recalled, lifts park at the main lobby floor with their doors open and cannot be moved away from the floor until the 'fire service' switch in the lift car is used to drive the lift, or until the main lobby recall switch is deactivated.

Under the current rules therefore, in the event of a fire alarm, all of the lifts will continue to operate on normal automatic control, answering car and landing calls, until such time as an 'authorised' person operates the fire service recall switch at the main lobby to recall the lifts. This method of operation allows the following in the period before the Fire services take control of the lifts:

- people to leave the building using lifts if they wish (assuming that they are aware of a fire in the building);
- people to enter the building using lifts, possibly unaware of a potentially dangerous situation;
- lifts to travel to a smoke or fire endangered floor, through someone pressing a car or landing button for such a floor, or because the fire caused a lift to stop at or near the fire floor.

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#### **4.1.5 Use of Lifts by the Fire Service Upon Arrival at a Fire**

The following points are noted in relation to some of the Melbourne Metropolitan Fire Brigade procedures documented for the use of lifts when arriving at Multi Storey Buildings in response to an alarm of "Fire".

- the officer in charge is to satisfy himself as to the safe means of access before using lifts or stairs;
- where installed the "Fireman's Lift" is to be used;
- if the fire floor is above ground level and a lift is to be used to gain access, Fire Service personnel are to travel to one floor below the fire (then proceed via stairs);
- if the fire call is to a basement floor, lifts are not to be used;
- the fireman's lift is to be manned by a member of the Fire Service at all times and to be equipped with a personal radio;
- the fireman's lift operator is to monitor all radio messages;
- movement of the lift is to be mainly under the control of "Location Control" and "Forward Control" officers of the Fire Service.

Procedures in other jurisdictions may be different. There is no 'standard' published procedure in use.

It is not clear from these procedures how the Fire Service officer in charge establishes that it will be safe to use lifts, either a fireman's lift or any other lift. The fire indicator panel within the building does not necessarily receive any data from points in the building that directly indicate lift safety or condition.

The Fire Service procedures do not address how and under what circumstances lifts should be recalled to the main lobby, how recalled lifts not immediately required by the Fire Service should be utilised (if at all), and how the management of the fire situation should be dealt with from the perspective of evacuation of people with disabilities. Refer also to Section 7.

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## 4.2 SURVEY FINDINGS (LIFT INDUSTRY)

Seven local manufacturers/organisations were surveyed, five of whom responded. Five overseas manufacturers were surveyed, but none of these responded.

The survey drew a reasonable response from local companies and useful information and questioning of the “use of lifts for evacuation” proposal was received. The main findings of the survey confirmed that the most likely cause of lift failure in the early stages of a fire was water entering lift shafts, causing electrical short circuits which would stop a lift from operating.

The following is a summary of the main findings of the lift industry survey:

- Water is likely to effect the landing door locks, door operator equipment mounted on the car top, lift car electrical equipment, and pit equipment.
- Smoke and heat are expected to effect the operation of the lift, although the time frame for this effect cannot be as readily estimated as it can with water.
- Failure or contamination of landing controls such as call buttons, hall lanterns and indicators, are not likely to effect lift operation, once fire service recall and control has been initiated.
- Lift landing doors (entrances) in close proximity to fire conditions (high temperatures) are likely to cause lift operation to be interrupted, despite their ‘fire rating’. Lift entrances can be expected to sustain a physical barrier when subjected to fire, but are unlikely to prevent heat being radiated into the lift shaft, or to maintain conditions in lift shafts that would allow lifts to continue to be used. If the fire test conditions for lift entrances were experienced during a fire near a lift, it is predicted that interruption to lift operation could occur within the first 30 minutes of such conditions, although this is unlikely to occur in a sprinkler protected building.
- Lift doorway protection systems (light ray door reopening devices) are likely to be effected by the presence of smoke, causing lift doors to be held open as if they were being blocked by a person standing in the entrance.
- Most respondents indicated that they supported the concept of automatic recall of lifts in the event of a Fire Service alarm being initiated. One respondent was concerned about the possibility of auto recall causing a lift to travel into dangerous conditions.
- Use of lifts under ‘fire service’ control should be carried out by trained authorised people.
- Redesign of lift equipment to resist the effects of water (and smoke) could probably be achieved, but the cost would be very prohibitive and the time scale for such redesign quite long, 12 months or longer.
- Many respondents indicated that it would not be economic or practical for them to redesign their products for requirements in Australia that were not commonplace in a substantial portion of other parts of the world. This is largely due to the fact that most of the lift equipment that would need to be modified, is designed and manufactured overseas.

The overall impression gained from the survey was that manufacturers and other parts of the industry are interested in finding ways to assist people with disabilities to use lifts for evacuation. However, this industry is generally quite conservative by nature and there is a perception that this problem cannot be solved easily.

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When discussing this research project with the survey respondents, most indicated that they had locally, or through their overseas principals, already started to consider ways to resolve the issues involved, and in some cases the matter has been under review for some time. Proposed solutions involving both the lift system and other building systems received favourable responses.

### **4.3 EFFECTS OF WATER, SMOKE AND HEAT ON LIFT OPERATION**

#### **4.3.1 Fail-to-Safe Operation of Lifts**

A lift system is designed on the principle of 'fail-to-safe', because it involves the use of large forces, is installed in potentially hazardous places (shafts), and it conveys passengers automatically in an enclosed car without the passenger having to control or being aware of the drives and the equipment used to move the lift.

There are many hazards present under normal operating conditions in lift cars and lift shafts, the main ones being:

- Entering the lift shaft when the lift is not at the floor (falling down the lift shaft).
- Being caught between the moving lift car and part of the lift shaft (crushing, striking, etc).
- Being struck by moving parts, especially the lift doors when entering or leaving the lift car.
- Over-speeding of the lift, resulting in the lift not stopping normally at the terminal floors.

Despite these hazards, lift travel is one of the safest forms of 'public' transport that the average person uses. This is because of the high level of safety precautions taken in the design of lift equipment. Australia's safety record for lift travel is recognised as being very high by world standards.

Under normal conditions this high level of safety, based on the fail-to-safe principle, is desirable and serves the industry well. Any single fault is designed to prevent the lift from moving in what might otherwise be dangerous circumstances. For instance, in the case of landing doors, there are two electromechanical locks which must both be closed before it is possible for the lift to move away from floor. The circuitry for these locks (known as the safety circuit) is also protected in a manner that causes a fuse to open when any earth (ground) fault or short circuit occurs, preventing any movement or operation of the lift.

This same safety circuit is wired into many other safety critical parts of the installation, and a fault or opening of the circuit at any point causes the lift to stop immediately. The safety circuit is present in places such as the lift well (door locks and limit of travel devices), in the pit, on top of the car, inside the car and in the machine room.

#### **4.3.2 Specific Hazards and Risks for Lifts During a Fire**

In addition to the hazards and risks noted above in relation to lift use under normal conditions, there are additional hazards that arise when lifts are in use during a fire in a building. These hazards can effect the occupants in lifts, either as they are travelling in a moving lift, or if they are trapped in a stopped lift.

The primary hazards for lift occupants during a building fire are considered to be:

- electric shock or short circuit due to the presence of water;
- exposure to high temperature, fire;
- asphyxiation/suffocation.

It should be carefully noted that these hazards are largely the same for all lift types, and "Fireman's Lifts" are exposed to these hazards to the same extent as other lifts.

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#### 4.3.3 The Effects of Water

In most circumstances water is the primary medium used for extinguishing a fire. In sprinkler protected buildings, water is applied to the fire automatically, and will continue to flow from those sprinkler heads which have operated until switched off manually. Once the Fire Service are in attendance hydrants and hose reels may also be used for final fire suppression and mopping up, but in sprinkler protected buildings, usually after the main threat from the fire has been dealt with.

In practical terms, water from sprinklers is the most effective means of controlling and suppressing fires in multi storey buildings. However, water is also an enemy of lift operation, as it has the potential to disrupt the safety features built into lifts, and cause the lifts to stop unexpectedly.

Water from sprinklers will pool on the floor in the vicinity of the sprinkler discharge, and progressively spread over all available areas until it reaches points where it can escape from the floor. Practical experience with accidental water discharge in buildings indicates that flow through a range of penetrations can occur.

In the event that water reaches the lift doors, it can then readily run over the door sill, into the lift shaft and down the front face of the lift well. The resultant waterfall effect will run down the well flushing which connects the sill of one doorway to the head of the next, and onto the projecting rollers and cams on the door locks. As the water hits projections on the front wall of the shaft it will be deflected out further into the lift shaft and onto the lift car (when the lift car is below the fire/water floor). Water reaching the pit will gradually fill the pit area unless there is a drained sump in place, which is generally not the case.

Whilst it would be technically feasible to design waterproof equipment for lifts, the cost effectiveness of such an approach to resolving interference from water is questionable, as is the certainty of this as a solution over the life of the building.

The following factors need to be taken into account:

- There is a very wide range of equipment in the lift well, on top of the lift car, inside the lift and in the lift pit which would have to be redesigned to provide sufficient waterproofing to withstand water seeping or pouring down a lift shaft.
- Preliminary estimates from lift manufacturers of the potential cost of such an equipment waterproofing exercise equate to approximately 5% to 7% of the cost of a normal lift installation (the extra cost is estimated to be of the order of \$5 to \$12 per m<sup>2</sup> of building area for new installations). Retrofitting is expected to be prohibitive in expense.
- It is probable that a design approach which restricts water from entering equipment, will also restrict maintenance access. This may then lead to circumstances where waterproof covers and the like are left off. In practice there are already known circumstances where mechanical safety protection guards get left off now.
- If the lift machine room were located below the lift, the risk of water ingress could be quite high, with little prospect of effectively waterproofing controllers, machines and the like.

A more certain method of dealing with the water issue would be to grade the floor on the lobby side of the lift door sills, so that the water would have to rise to a predetermined depth on the fire floor before it could run into the lift shaft.

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Estimates have been conducted on the height the sill may be required to be raised. For a typical fire in which two heads discharge on a small floor of say 800m<sup>2</sup>, a height of 16mm would allow around 30 minutes of lift use after sprinkler activation assuming there are no other drainage paths in existence. It is further estimated that if construction tolerances were to reduce the nominal 16mm to say 10mm, then the water would be held for about 20 minutes. It is envisaged that the 16mm could be taken up in the design of the lift lobby floor and in the zone between the lift door track and the outer face of the lift door architraves (usually about 200 to 300 mm). On larger floor plates the rate of water build up is likely to be slower due to the larger floor area available to disperse the water. Note that the above figures have been estimated somewhat conservatively, and assume for instance that the water disperses over only approximately 50% of the available floor area, due to the likely effects of partitioning and the like. Other floor penetrations as occur in most existing buildings are expected to extend the time for filling.

Other methods of preventing water from entering the lift shafts could also be considered, including the provision of permanent floor drainage outlets in the vicinity of lift lobbies and lift entrances.

Note that where the Fire Service or others use hose reels or hydrants to fight the fire, the rate of water build up is expected to be very much faster, depending on the amount of use. Under these circumstances, the proximity of water to the lift entrances would need to be carefully monitored. It is envisaged, however, that 'authorised' users of hose reels and hydrants would be doing so, in the knowledge that their actions will increase the likelihood of water entering the lift shafts, and with the 'approval' of those coordinating lift use and safety.

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#### 4.3.4 The Effects of Heat and Smoke

The BCA calls for lift landing entrances to have an FRL of -/60/-. This level of fire resistance requires the lift entrances to resist the passage of flames, but not to have any insulating characteristics. Thus, heat will penetrate into the lift shaft if any substantial level of fire occurs in the immediate vicinity of the lift entrances in the lift lobby. Lift landing doors by their nature have gaps around their sides, top and bottom, to allow unrestricted door movement when the lift car doors couple, unlock and drive them open/closed. As a result there exists an inherent smoke path at each entrance up to 6mm around the perimeter of the doorway. This equates to some 0.25 m<sup>2</sup> for a lobby served by six lifts, a not uncommon situation.

The hazards arising from heat and smoke at the lift entrances and inside the lift shaft are likely to include:

- In uncontrolled fire conditions, it is probable that the lift entrances themselves will become inoperable because of buckling and distortion, causing them to foul a passing lift car or trip the safety circuit when a car is passing the floor. Note that landing and car doors have very small clearances between them as the lift passes each floor. Small deflections of the landing door equipment (locks and rollers/cams) is likely to cause the locks to be 'tipped' by the car, opening the safety circuit and stopping the lift.
- Electrical equipment and cabling in the lift shaft can be effected by heat, notably the flexible trailing cables supplying power, safety circuit and control signals to the lift car.
- Similarly, heat can damage and render inoperative, equipment mounted on the lift car, causing the lift to stop at some point in the lift shaft where its occupants are exposed to heat and smoke.
- A lift car stopped at a fire floor or a short distance above it, can be expected to expose its occupants to heat and smoke, even if the landing entrance at the fire floor is closed.

Sprinkler control of a fire is likely to mitigate most of these possibilities.

The hazards arising from smoke at the lift entrances and inside the lift shaft are likely to include:

- Smoke in the lift car doorway is likely to cause light-ray type door passenger protection systems to hold open the lift doors and prevent them from closing, exposing passengers in the lift car to smoke and consequent injury. The time the doors are forced to stay open due to smoke blocking, the entrance will vary depending on the way in which the doors are controlled. On lifts fitted with 'nudging' the doors will close at reduced speed after a pre-determined period, often set to around 15 to 20 seconds.

This timer is reset each time the lift stops at a floor, and thus, if the lift travelled to a number of smoke logged floors, the cumulative time that the lift waited at all floors in smoke conditions could be quite long. On lifts not fitted with 'nudging' the lift doors could be held open by the smoke indefinitely.

- Where a lift is stopped or travels above a point in the lift shaft where smoke enters, there is a risk of smoke entering the lift car and causing injury to occupants. Lift cars are designed to have a defined (minimum) amount of natural ventilation, to prevent a stopped lift car under normal conditions becoming hazardous through the trapped passengers exhausting all of the available oxygen in the lift during the period they are trapped inside. This same precaution in a smoke logged lift shaft could lead to a smoke hazard under fire conditions.

Protecting the lift doors, by a lobby providing a barrier to smoke travel, is expected to mitigate the above hazards to an acceptable level risk in sprinkler protected buildings.



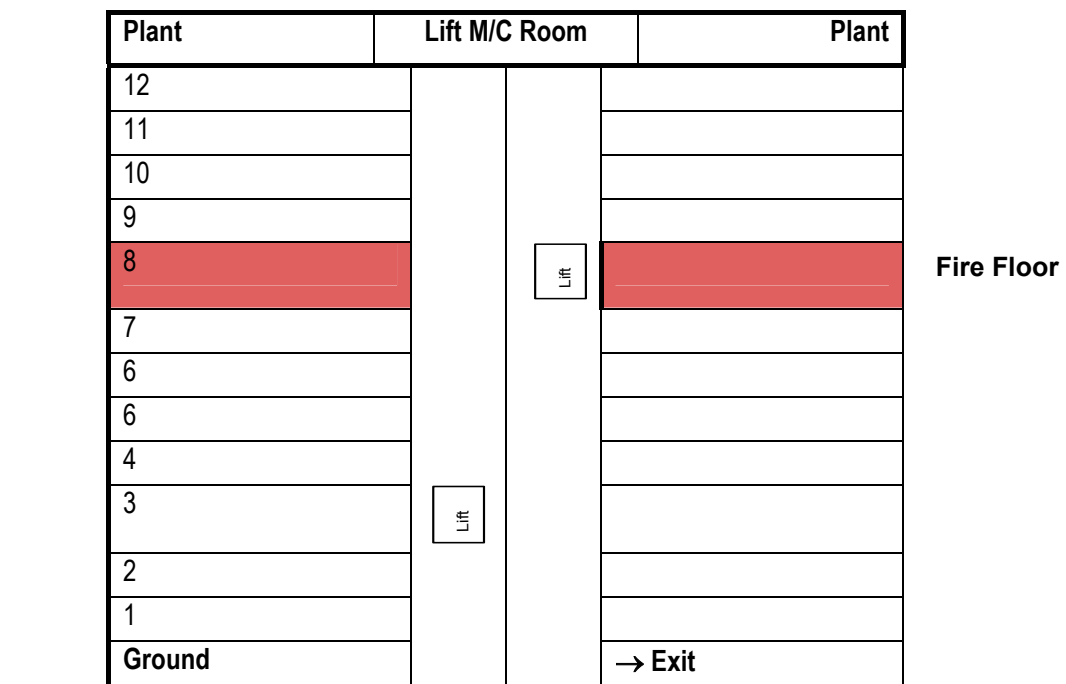
#### 4.4 EVACUATION CAPACITY AND CONTROL

In order to address the capacity required of a lift system that may be used to evacuate people with disabilities from a fire floor (or a floor in close proximity to fire), it is first necessary to determine how many people will require evacuation and how they might be evacuated. For the purposes of analysis a simple typical scenario has been examined to ascertain the limits of any proposal to use lifts for the evacuation of both people with disabilities and those without disabilities.

The typical scenario studied comprise a building of Ground plus Twelve typical upper floors, each with a net area of some 1,200m<sup>2</sup>, occupied at a conservatively high designed density of one person per 10 m<sup>2</sup>. On each floor, 6% of the 'design' population were assumed to require evacuation by lift because of some form of mobility or other disability. Only the fire floor, two floors above the fire floor and the floor below the fire floor were considered for evacuation. Under these circumstances, approximately 29 people would need to be evacuated via lift from the fire affected floors.

Using the computer program "Elvac" which was developed by John Klote and Daniel Alvord (Ref 12) for the purpose of estimating evacuation times using lifts, two strategies for evacuation of building occupants were evaluated. An assessment of the validity of this program for this purpose was first conducted to verify that the results obtained are sufficiently accurate for the purposes of this study. The program is considered appropriate for these purposes.

The first strategy involved all people with disabilities using the lifts to evacuate from the fire effected floor(s), and everyone else using the stairs. The second strategy looks at everyone on the fire effected floor(s) using the lifts to evacuate.



In evacuation mode, lifts under fire service control are used to shuttle people away from the fire floor.

The output of these studies are set out in Appendix '2', and indicate the following times to evacuate the fire affected floors, from the sounding of the Alarm signals to do so:

- Only people with disabilities evacuate via lifts on the fire floor only, evacuation time for one floor would be 6.4 minutes.
- All people are evacuated via lifts, on the fire floor only, total evacuation time for one floor would be 10 minutes.

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- Only people with disabilities via lifts, total evacuation time for four floors would be 9.3 minutes.
  - All people are evacuated via lifts, total evacuation time for four floors would be 23.8 minutes.

Assumptions for these studies include:

- The fire is on the 8<sup>th</sup> floor, and evacuations take place on the 8<sup>th</sup> only or 7<sup>th</sup>, 8<sup>th</sup>, 9<sup>th</sup> and 10<sup>th</sup> floors.
- Four lifts serve the building, but one of them is not used for evacuation, to allow it to be used for other management tasks and/or by the Fire Service when they arrive.
- On site response to the fire alarm and warden responses enable the lift evacuation to commence within five minutes of the alarm being raised.
- There will be sufficient warden personnel available to operate the required number of lifts (in this instance, three wardens).

Note that in the case of evacuation by lift of only people with disabilities, the number of people being carried on each trip was quite low (three per trip), to take account of the additional space requirements that might be encountered for these people. In the case of full evacuation of the building, ten people per trip are carried, compared to a typical rated car capacity of 16 to 23 persons.

The following general conclusions may be drawn from these studies:

- If on site management/wardens can commence evacuation of people with disabilities within five minutes of the alarm being raised, evacuation can be achieved well before the 20 minute period when water is expected to threaten lift operation. The studies presented later indicate that egress from the fire floor to either stair or lift lobby is likely to be completed within this time-scale
- It does not appear feasible for the whole of the population on the potentially four fire effected floors to be evacuated via lifts before the estimated (sprinkler) water threat period is reached, 20 minutes from sprinkler activation.
- As the lifts are least likely to be under threat during the early stages of the fire, local on site management of evacuation for people with disabilities via lift should be undertaken at this stage.
- Central warden control needs to concern itself with control and use of the lifts, and communication with floors effected by fire.
- Floor wardens need to assist people with disabilities requiring lift evacuation to assemble at the lift lobby as quickly as possible, and that the need for such evacuation is communicated to the central warden point.

#### **4.5 CONTROL AND COMMUNICATIONS**

From the above discussions of the various hazards and risks arising from the use of lifts generally, and in fire situations in particular, it can be seen that information about the state of the lifts and conditions likely to influence their operation are important factors in deciding when and how to use the lifts for the purposes of evacuation. This information should also be used by Fire Service personnel fighting fires to minimise risks they face when using the lifts.

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The advanced nature of a present day Fire Indicator Panel (FIP) allows 'intelligent' response to smoke and sprinkler alarm situations to be contemplated, including the automatic response of lifts to such alarms. Advanced FIP's can process alarm inputs and provide information to other systems on the specific locations of various alarms in the building. This data can be used to provide a conditioned response by the lifts in the event that a fire is detected.

Opportunities for wider use of 'open' building information systems is likely to enhance performance in the future.

#### **4.5.1 Automatic Lift Recall**

Regulatory authorities and the lift industry generally in Australia, have in the past resisted moves to allow lifts to be recalled automatically on the basis of a fire alarm. If auto recall were to be initiated in the event of a smoke alarm alone, the likelihood of false alarm lift recalls would be quite high. Whilst the potential for sprinkler alarms because of damage to sprinkler heads rather than activation by heat exists, the rate of such alarms is quite low.

The existence of a significant amount of smoke in a sprinkler protected building without sprinklers being heat activated is possible (due to a smouldering fire), but rare and unlikely in an occupied building.

Thus it is considered valid to propose that automatic lift recall be allowed in circumstances where sprinklers alone or both smoke and sprinkler alarms have been activated. Automatic recall does not preclude manual recall being implemented by warden staff on site. The benefits of this form of automatic recall include:

- Lifts recalled to the Ground Floor to empty passengers and allow building management to enter and control lift, but are less likely to be recalled under non fire conditions.
- The lifts will not be used by people in the building that do not need to be evacuated by lift.
- People entering the building and those already in the building will be prevented from unknowingly travelling to a fire effected floor via the lifts.
- Recalled lifts will be parked ready for use by wardens to evacuate people with disabilities.
- Any lift being held at a floor due to smoke blocking the door passenger protection light ray system will be recalled, as the recall control by-passes the light ray system.

In tall multi-lift rise buildings, the automatic lift recall function need only be applied to the actual rise in which the sprinkler/smoke alarm occurs. If an alarm occurs that effects a transfer floor, then both rises would be recalled. This selective recall approach in large buildings is in line with the initial response strategy of current evacuation procedures used, and avoids unnecessary overloading of fire escape stairs by evacuating only the effected rise.

Some form of manual override of the automatic recall system would be advisable to enable service to be restored in the event of malfunctions.

#### **4.5.2 Lift Controls Under 'Fire Service'**

The existing lift system 'fire service' control function, as defined by AS1735.2 (clause 29.6) and called-up in the BCA Section E3, already provides a wide range of facilities and precautions that give operators certainty about what to expect and full manual control over lift movement and response. Under 'fire service' control, the lifts will not respond to landing calls, and car calls are entered and can be changed or cancelled entirely at the discretion of the person driving the lift.

Provided the person operating the lift under 'fire service' control is properly trained in the capabilities of the system, the lift can be taken to any floor irrespective of the status of that floor under normal operating conditions.

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The key issue for the person in a lift under 'fire service' control, is awareness of conditions outside the lift shaft, so that they can avoid taking the lift to a floor under threat. Whilst there are many ways in which information from the FIP and other sources could be fed onto an information display in each lift car for use by the operator, the interpretation and response to that data is likely to vary from one operator to another, and may lack any coordination with other events taking place outside the lifts.

A reliable and readily available communication system between each lift car and the FIP and head warden locations is proposed as the most effective means of managing the use of lifts for evacuating people with disabilities. Such system need not be permanently mounted in the lift car, but permanent communication wiring to each lift is considered appropriate.

#### **4.6 LIFT SIZES**

In some buildings there may be only one lift, sized and designed to function specifically as a lift suitable for use by people with disabilities. However, the trend in recent office buildings for *all* lifts to be at least large enough to carry wheelchairs, which is usually the most space consuming need.

Lift cars that will be used for evacuating people with disabilities will be the same as those serving the building under normal conditions of use. In most class 5 office buildings over 25m in height, it would not be practical or normal for lifts of less than 13 passenger capacity to be installed. A lift of this size is suitable for carrying wheelchairs provided minimum car dimensions are provided. Larger lifts are generally able to accommodate wheelchairs.

AS1735.12 (which has recently been updated) provides guidance on the minimums required. It is expected that all lifts that could be used to evacuate people with disabilities in Class 5 buildings over 25m in height, would be design to the minimum size requirements of this standard as required by the BCA.

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## 5. FIRE SCENARIOS

### 5.1 RATE OF FIRE STARTS

There are many fire starts to which the fire brigade are not called due to the fires being self extinguished or put out by the occupants. The existence of such fires is supported by anecdotal evidence [4], from data for particular buildings on the use of fire extinguishers versus the number of times that the fire brigade have been summoned; and from survey data associated with particular buildings. Firm data on this matter has been obtained by the GVB/AIB [5]— a Swiss insurance and regulatory organisation. This organisation maintains excellent records of both fire brigade call-outs and insurance claims. Their records indicate that for every three insurance claims relating to fire there is only one call-out to the fire brigade. Furthermore, it is known that there are many additional fires for which no insurance claim is made and the ratio of actual fires to those resulting in a call-out to the fire brigade is estimated as being between 5 and 10. It is assumed in this report that four out of five fires do not result in a call to the brigade. This means that 80% of fire starts will *not* result in brigade attendance. Thus, these are very small fires.

According to a recent analysis of fires in office buildings in the United States [6], it is found that for *non-sprinklered buildings*, 70% of fires *reported* to the fire brigade<sup>1</sup> are limited to the object or area of fire origin. During occupied hours, close to 90% of fires are confined to the object of origin or area of origin.

Therefore, only a relatively small proportion of fires ( $0.20 \times 0.10 = 0.02$  or 2%) are likely to extend past the room of fire origin during occupied hours—even *without the presence of sprinklers*.

It is these latter fires that could lead to life threatening situations and which may result in significant damage if they are permitted to spread throughout a floor and to several floors.

The likelihood of fires extending beyond the room of fire origin (which are small in number as discussed above) is very much less if the building incorporates a standard sprinkler system.

As part of the study of the 140 William St building, in Melbourne, a detailed review of documented fires in high rise office buildings was undertaken [7]. This review revealed that there have been no significant fires, and more importantly, no deaths in *sprinklered* high-rise office buildings anywhere in the world. It follows that sprinklers are an essential part of the fire-safety system. If a more reliable sprinkler system is incorporated, the probability of such an occurrence is significantly less again.

### 5.2 EFFECTIVENESS OF SPRINKLER SYSTEMS

The effectiveness of a sprinkler system can be taken as the product of the system reliability (ie. will it discharge water?) and the system efficacy (will it discharge sufficient water?). Both factors are important. Fire tests conducted at BHP Research [8] have shown that sprinklers are very effective in extinguishing fires or controlling fire spread in office buildings—even assuming an extra-light hazard system. The efficacy of the sprinklers installed in accordance with AS 2118 can be taken as close to unity for these buildings.

The reliability of sprinkler systems in Australia and New Zealand is generally accepted as being high (>98%). If we consider a sprinkler system, the following are possible reasons why there may not be water at the sprinkler head:

- (i) no water to the building due to mains breakdown or total isolation

The chance of this happening for Grades I and II water supply systems is extremely small. Analysis based on mains frequency breakdown for metropolitan Melbourne indicates a figure of less than 0.000001 failures per year for a typical building. In the case of a building with a Grade III supply, this could be up to 0.02 failures per year.

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<sup>1</sup> This number, therefore, does not include many of the smaller fires that do not result in the fire brigade being called to the building.

- 
- (ii) water supplied to the building but no pressure due to failure of pumps

The requirements for dual fire pumps (either powered by a diesel or electric motor) with Grades I and II (as defined in AS 2118.1) systems makes the likelihood of this occurrence fairly small. Indicative failure probabilities are estimated as:

Pump system set-up	failures per year
diesel & diesel (no systematic maintenance)	< 0.02
diesel & diesel (maintained weekly)	< 0.0002
diesel & electric (no systematic maintenance)	< 0.0005
diesel & electric (maintained weekly)	< 0.00005

The provision of an external booster connection for the fire brigade provides the necessary back-up should the pumps associated with the sprinkler system fail.

- (iii) blockage within pipe work such that a sprinkler branch is isolated

Provided the system is adequately commissioned and subsequent tenancy work undertaken by qualified and competent fitters, it is considered that the likelihood of this occurrence is extremely small.

The use of end-of-line testing could further provide a check on this matter. Provided the above is the case, the probability of this is considered to be much less than that associated with (v).

- (iv) sprinkler head operates but debris introduced into pipe work blocks this isolated sprinkler head.

Again, this is considered to be extremely unlikely especially if proper commissioning has taken place. In any case, the chance of two adjacent heads being blocked in this manner, will be close to zero. The probability of this occurrence is so small that the possibility can be ignored.

- (v) system has been unintentionally or intentionally isolated at stop valve

With required monitoring of all valves back to the fire station, the likelihood of this occurrence is extremely small. If the valve is closed without notifying the Fire Brigade it is the current practice of the Brigade to send a member of their staff to investigate the fault.

- (vi) part or all of the sprinkler system is isolated for tenancy modifications

It is this factor that has the biggest influence on reliability and the time which the system is isolated will almost entirely dominate the final calculated value of reliability—especially for high-rise office buildings.

Car park and residential buildings require isolation of the sprinkler system only very rarely (eg. for servicing of valves) whereas office buildings may require fairly regular tenancy modifications. It has been estimated that, on average, every second floor in an office building per year will require isolation of the sprinklers for modification purposes. During these periods sprinkler coverage may not be available.

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Accordingly, factors (i.) - (vi.) give a sprinkler reliability for a high-rise office building of around 98% assuming that many floors (as many as allowed by AS2118) are connected to the same isolation valve. However, if each floor can be isolated by a single valve (a subsidiary valve), and if the isolation of such valves is minimised through good management procedures and electronic monitoring, then the average sprinkler reliability will be considerably higher than the above value.

Nevertheless, a 98% reliability is a high percentage; and this, combined with the presence of occupants who are awake and aware, means that it is very unlikely that a major fire will develop within sprinklered office buildings. This conclusion is supported by field experience.

### 5.3 RELEVANT DESIGN FIRES

What design fires should be considered with respect to the evacuation of the occupants within a building? Since the buildings which fall within the scope of this research are sprinklered buildings it is recommended that the appropriate design fires should be sprinkler controlled fires. Should a major fire (non-sprinklered) develop within the building, a number of uncertainties will be introduced due to the fire characteristics. This will substantially increase the hazard to **all** occupants due to the failure of zone pressurisation, failure of floor-to-floor isolation, loss of tenability of the stairs. The incorporation of sprinklers within the building seeks to avoid these additional uncertainties.

### 5.4 FIRE SCENARIOS

Having proposed that the relevant design fires are sprinklered fires, it is necessary to define the relevant characteristics associated with these fires that can have an impact on the occupants. The characteristics associated with these fires can be broadly described as the fire scenarios. How can a sprinklered fire be characterised? Traditionally this characterisation is undertaken by assuming a rate of heat release versus time relationship, truncating at the time of sprinkler activation, and then determining the height and temperature of the resultant hot layer. Once these characteristics are known, the impact on any exposed occupants can be determined. The difficulty with this approach is firstly that the mixing effects of the cool layer and the upper hot smoke layer associated with the sprinkler action are not modelled. Secondly, the fire is not a steady state fire but will eventually be extinguished through the action of the sprinklers.

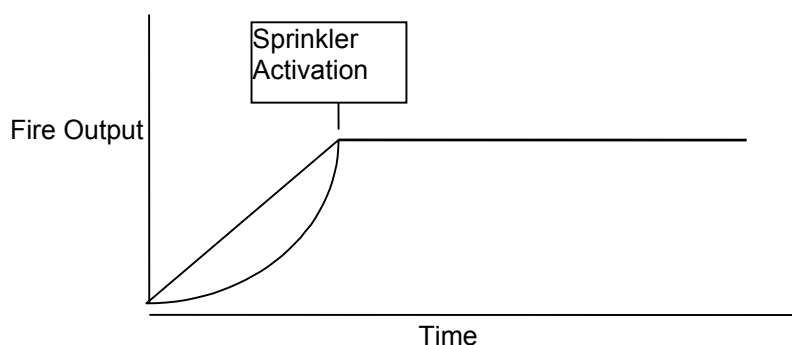


Figure 1 - Generic graph of 'controlled' fire

For the purpose of this study it was decided to test the fire scenarios through experiment. To this end, experiments were conducted with a representative work station and sprinkler layout. The details of these tests are described elsewhere but it is sufficient to note that the choice of work station and sprinkler head location is considered to be representative of a "worst case" sprinklered fire. Smoke levels and temperatures were measured within the test enclosure which has a plan area of 12m x 33m being representative of a floor in an open-plan high-rise office building. The interaction of the return air fans on smoke was directly taken into account.

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The above tests gave relevant data on smoke and temperature conditions for a fire starting in an open-plan situation. This was judged as being the most critical situation. A previous sprinklered test within an office enclosure directly adjacent to an open-plan area [9] found that conditions within the open-plan area were tolerable and less severe than those which could develop should the fire be initiated within the open plan area.

What conditions are likely to develop within the lift shaft or the upper floors of the building? Smoke will only enter the lift shaft if the lobby becomes smoke logged. If smoke enters the lift shaft, then it will be substantially diluted due to the mass of air and mixing due to the piston effect. The conditions within the lobby are expected to be much worse than the conditions within the lift shaft. If the lift lobby is kept tenable then the lift shaft will also be 'free of smoke'. This issue is discussed in more detail elsewhere. As far as the floors above the fire are concerned, these can be assumed to be free of any threat from smoke due to the limited smoke production from a sprinklered fire, smoke separation of levels, and smoke managements systems, it being only *necessary* to evacuate persons on the fire floor.

In order to compare the scenario of evacuating the fire floor only (as considered necessary), the practice of considering the evacuation of one floor below, the fire floor and two floors above, was tested by lift performance analysis. This wider analysis reflects what is understood to be widespread practice although a rational basis for this practice has not been identified in the literature.



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## 6. BUILDING SERVICES

The following sections briefly outlines the expected building services in place.

### 6.1 AUTOMATIC SPRINKLER SYSTEM

The scope of this report assumes the inclusion of an automatic sprinkler system in the trial design. The code requirement for a sprinkler system comes from Performance Requirement EP1.4 and the deemed-to-satisfy requirement E1.5. The deemed-to-satisfy provision of the code references compliance with AS 2118. The fire tests have been constructed based on an light hazard spacing as defined in AS 2118. Ordinary Hazard spacing and water flow requirements which are more commonly found in office buildings are expected to produce better results in terms of fire control and therefore are still relevant to the study.

### 6.2 SMOKE DETECTION SYSTEM

Office buildings of the size included in the study according to current deemed-to-satisfy provisions require a smoke detection system. The code requirement for a smoke detection system comes from Performance Requirement EP2.2 and the deemed-to-satisfy requirement E2.2. The deemed-to-satisfy provision of the code references compliance with AS 1668.1 or AS 1670. The presence or otherwise of a smoke detection system is not critical to the outcome if evacuation of one floor only is considered.

### 6.3 SMOKE MANAGEMENT SYSTEM

Office buildings of the size included in the study require a smoke hazard management system. The code requirement for a smoke detection system comes from Performance Requirement EP2.2 and the deemed-to-satisfy requirement E2.2. The deemed-to-satisfy provision of the Code references compliance with AS 1668.1. The presence or otherwise of a general smoke hazard management system (the principle of objective of which is to maintain evacuation paths free of smoke and curtail smoke travel between floors) in office buildings is not necessarily crucial to the outcome of the study.

The essential feature of such systems insofar as this study is concerned is the ability to prevent smoke compromising access to or operation of the lifts. This feature is seen to need both physical barriers and air management systems for the achievement of this performance. These are not necessarily required under the present BCA provisions.

### 6.4 EMERGENCY WARNING & INTERCOMMUNICATION SYSTEM

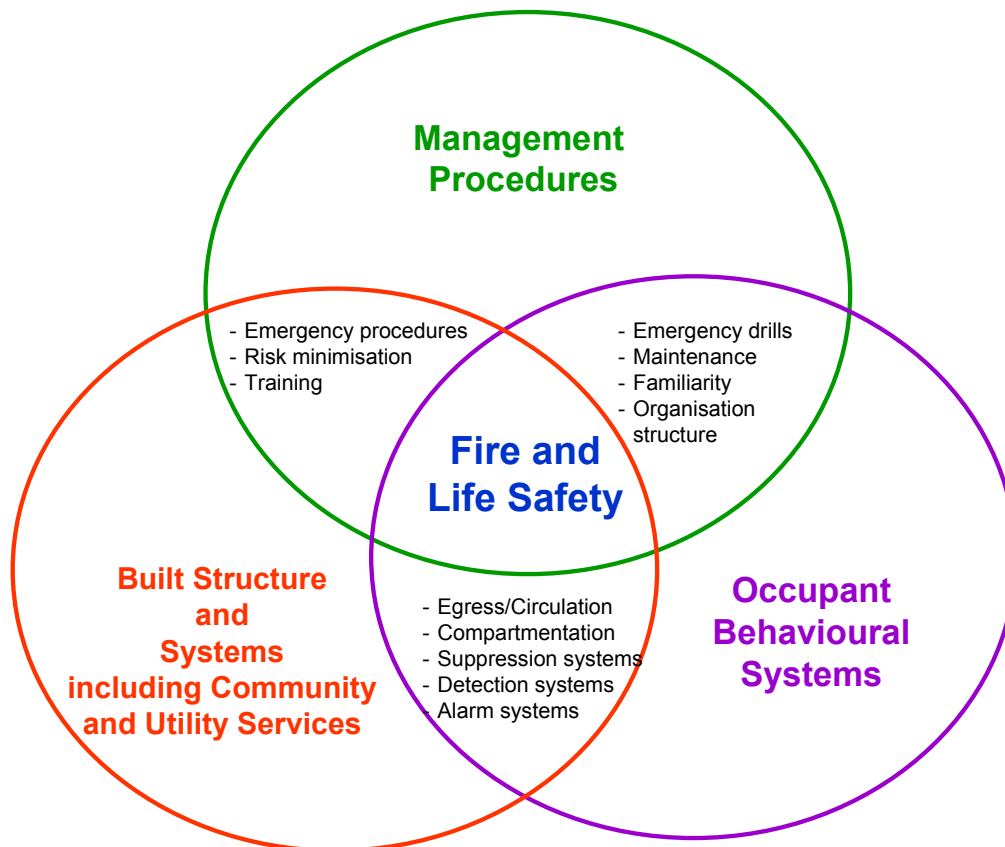
Office buildings of the size included in the study require an EWIS system. The code requirement for an EWIS system comes from Performance Requirement EP4.3 and the deemed-to-satisfy requirement E4.9. The deemed-to-satisfy provision of the code references compliance with AS 2220.2. The combination of tone signals alone, in the absence of an appropriate emergency management system may not achieve adequate response times. Use of informative emergency warnings can assist in achieving adequate response times [14].

The presence of effective information and communication systems is seen as essential to the achievement of effective egress for all occupants.

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## 7. MANAGEMENT SYSTEMS

Sections A-H of the BCA deal with the required built systems to be installed in a building to provide an acceptable level of safety for the occupants. However, built systems are only a component of the overall building design which effect the level of safety in a building. The other key elements, which are not covered in the BCA, are Management Systems and Occupant Behaviour.



The figure above shows the interaction between the elements which constitute Fire and Life Safety. This is especially important when considering evacuation of people with disabilities.

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## **7.1 BUILDING MANAGEMENT**

### **7.1.1 Evacuation**

#### **BCA Requirements**

Currently the BCA does not directly address building management. The requirements for building management intervention in the event of a fire currently comes from other legislation such as Occupational Health & Safety. The direction of the BCA though is to include all relevant legislation which relates to the installation, maintenance and management of a building and its services.

The current BCA only covers the 'maintenance' of building systems (in Section I). The existence of systems or hardware does not necessarily mean that their intended purpose is being achieved. Management of a building under emergency conditions is one of the items to be addressed.

One of the items crucial to the outcome is the recognition of building management standards. The Australian Standard "Emergency Control Organisation and Procedures for Buildings", AS 3745, is currently not referenced in the BCA. The inclusion of a suitable standard will bring a more complete view of building safety to the BCA.

Effective evacuation management will require both effective information gathering and communication. Once an effective communication procedure is in place, sufficient staff training to implement the system will be required. The importance of staff training is highlighted in Section 3 of AS 3745. As a result of the building management questionnaire, carried out during this study, it was apparent that most buildings had a procedure in place. However, the frequency of drills and staff training sessions varied considerably.

Whether the level of information and communication protocols were sufficient was not evident from the responses.

#### **The "Buddy" System**

In utilising staff to assist with the evacuation process, an effective way to assist people with disabilities is the implementation of the "buddy" system. This relies on able staff members being assigned to a person with a disability. Their duties include warning the person and assisting them to a safer place. This may be to the lift lobby or outside the building as required. The downfall of this system is that it requires the "buddy" to be present at the time of an emergency. This may be a problem any time the "buddy" is not present (eg sickness, holiday, etc.). For this reason, it is suggested that multiple "buddies" assigned to each person with a disability could be necessary. However, this does not solve the problem in cases where the person with a disability is alone such as if they are working after hours. Therefore this procedure must be viewed as an added level of safety but not relied upon as the only system required.

#### **Lift Operation**

Another procedure that must be reviewed is the management of the lifts in an emergency. Section 4 of this report discusses the modifications to the automatic fire mode operation of the lifts. However, the way that management then utilise the available lift must also be considered.

### **7.1.2 Maintenance and Verification**

While it is important that building management has a well constructed evacuation plan it is essential that the actual performance is verified and recorded. There are many standards and guides which cover management's requirements on the maintenance of essential services. In addition to the issues of maintaining clear evacuation pathways, limiting fire loads in critical areas and implementing management procedures which reduce fire starts, the verification of emergency management procedures and actual drills is important. A changed requirement of using lifts will add to the complexity of achieving this performance.

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## **7.2 FIRE SERVICE**

### **7.2.1 Fire Fighting**

The use of lifts as part of fire fighting activities is expected, pursuant to the requirements of the BCA for 'emergency lifts' which appear to have been prepared in contemplation of such use.

The protocols for use of 'emergency' and other lifts in fire fighting are not formally published beyond the individual fire service agencies and hence not well understood by building designers or managers.

It would appear that such protocols do not include specific procedures for the safe use of "emergency lifts" except for a practise of using them to travel to the floor(s) below that from which a fire alarm emanates.

The threats to firefighters using lifts, 'emergency' or otherwise, in sprinkler protected buildings, are little different to those which might apply to the normal occupants of the building, except where firefighting procedures include shutting down power supplies, which might inadvertently effect lifts. These threats are discussed in Section 4. The means to address those threats, which might influence the safety of people using lifts under fire conditions, are discussed in Section 4 and in Section 9.

As firefighters are understood to utilise Breathing Apparatus when attending multi- storey fire calls, it is likely that the threat due to smoke is less than that for the normal occupants. However, as attendance and subsequent potential use of lifts by firefighters is later than the period during which the normal occupants might use lifts, the probability of smoke spread to lift shafts is higher

No evidence has come to light of sprinkler water discharge compromising lift operation during a fire although there are reports of firefighting hose streams adversely affecting lifts.

In summary, it is evident that further attention to developing access and firefighting protocols for firefighters using lifts is required. Within the scope of this study, it appears that the practise of accessing high rise floors in sprinklered buildings in order to undertake firefighting activities is capable of continuing. It is likely that those measures considered relevant to achieving safety for normal occupants to evacuate building via lifts will have an effect of improving the level of firefighter safety in gaining access.

The MFB 'Standard Operational Procedures (SOP's) require that, "Where installed, the fireman's lift must be used". It is expected that SOP's for other jurisdictions will be similar.

### **7.2.2 Evacuation by Fire Services**

The role of fire services in managing evacuation of high rise buildings, whether sprinkler protected or not, is far from clear.

The management of emergencies, fire or otherwise, is not directly prescribed in the BCA.

A potentially relevant standard, AS 3745, 'Emergency control organisation and procedures for buildings' recognises the need to inform the Fire Service of a fire alarm but does not recognise the potential for conflict of authority following the arrival of the Fire Services people on site. AS 3745 recognises the possibility of use of lifts under the control of "combating Authority personnel" (such authority is not defined) to evacuate mobility impaired people.

There is no reference in AS 3745 to joint training with the fire service.

There are no widely published fire service protocols establishing a hierarchy of control ( beyond the fire service) on a site where a fire exists. The MFB (SOP's) for Multi Storey Buildings references 'the Chief Warden of the Building supervises evacuation under the direction of the Officer in Charge' and "the responsible staff member supervises evacuation under the direction of the Officer in Charge".

The SOP's are silent on what the fire service are to do in the absence of a Chief Warden or responsible staff member.

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In the light of the foregoing, it is appropriate for both the fire service protocols and the BCA (or referenced documents, possibly AS 3745) to provide increased and integrated guidance in management of evacuation of both people with disabilities and other building occupants. This is discussed at greater length in Sections 4, 7 and 11.

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## 8. EVACUATION

### 8.1 QUESTIONNAIRES

The results of the questionnaires sent to the building owners and managers showed a definite trend in how evacuation is currently managed in buildings. The trend of evacuation procedures was:

- Floor warden warns the person with a disability of emergency
- Floor warden assists person to either lift or stair.
- Floor warden contacts chief warden and advises location
- Floor warden (or nominated person) stays with the person with a disability until Fire Brigade assists in evacuation from the building.

The point to note is that these procedures depend heavily on the Floor warden. This may make it difficult for them to perform their other duties in overseeing the evacuation of the remainder of people on the floor. The other point is that the Fire Service personnel are expected to help the person with a disability evacuate from the building. This extends the time that the person may be exposed to hazardous conditions and also increase the activities required by the Fire Service before they are able to address fire fighting activities.

### 8.2 OCCUPANT RESPONSE TIMES

While egress or movement time is an important aspect of the total evacuation time, the most important and most variable part of evacuation is the pre-movement or response time. The response time is dependant on many variables which cover both the building systems and occupant characteristics. While the method in Section 12 of the Fire Engineering Guidelines [13] is generally accepted to over estimate the response time of occupants, the factors listed which affect response time are still relevant.

In comparison, people with disabilities may have a longer response time for two reasons:

- either their disability is such that they are not made aware of the alarm, or
- their disability is such that once they have received and recognised the alarm they require more time before they begin to evacuate.

It is conceivable that a single occupant could be delayed by both of these factors.

The quality of information conveyed to all occupants has been investigated by some (14) and is highly relevant to both minimising response time and effective management of evacuation.

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## **8.3 DISABLED EGRESS PROVISIONS**

### **8.3.1 Reaction Time for People with Disabilities**

When considering reaction time for people with disabilities it is difficult to provide a broad statement as to the time required for people with disabilities to evacuate a building.

Issues such as the type of disability, the age of the person with a disability, the location of the person on the floor to be evacuated and the availability of any “buddy” system do not support the clear use of specifications, however, are some of the factors which must be considered.

Notwithstanding the above issues, the size, type of building and internal facilities also impact upon reaction time. This includes factors such as the type of doors present, the floor surface, and the dimensions of paths of travel to name but three.

For example a person who has a severe hearing impairment will have a variant evacuation time dependant as to whether the building has visual alarms, the seating position of that person in relation to any visual alarms present, and the presence of any designated “buddy” and the “buddy’s” actual location in the building.

Bearing the above in mind, the development of consistent building facilities to assist in evacuation of people with disabilities is imperative. However, an alignment of these with the development of appropriate management plans is equally important.

### **8.3.2 Factors influencing egress (reaction time) of various disability types**

#### **Mobility Impaired**

- Accessibility of the path of travel to the egress point  
(effect: 80%)
- Any change in the building surface due to fire. This may include water and loss of traction  
(effect: 50%)
- Stairs have a major impact on a person with a mobility impairment  
(effect: 30%) to an ambulant person with a mobility impairment  
(effect: 100%) to a wheelchair user

#### **Visually Impaired**

- whether or not audible alarms are present  
(effect 25%)
- if the above are present, the location of the vision impaired person in relation to the audible alarm  
(effect 25%)
- whether or not the person has a buddy to assist them to an egress point (effect: 25%)

#### **Hearing Impaired**

- whether or not visual alarms are present  
(effect: 50% - 100%)
- if the above are present, the location of the hearing impaired person in relation to the visual alarm  
(effect: 50% - 100%)
- whether or not the person has a buddy to assist them to an egress point (effect: 25%)

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## **Intellectual Disabilities**

- confusing circumstances and panic  
(effect: 50% - 100%)
- whether or not the person has a “buddy” to assist them to an egress point (effect: 50%)

### **8.3.3 Conclusions / Discussions**

Essentially, evacuation relies on the occupants realising a threat and moving away from it to a safe area. While built systems can be put in place to assist people with disabilities with some definite benefits, it is difficult to address all possible scenarios. A much more flexible solution is to rely on people interaction and management intervention which can cope with a wide range of scenarios. Thus the presence of a buddy system and a strong management strategy seem the most important factors to increase the chance of a successful evacuation.



## 9. ANALYSIS

### 9.1 FIRE AND SMOKE SIMULATION

A computer simulation of a possible fire scenario was carried out. The model was based on the typical office building defined in Case 2 of this section. The fire profile in line with the expected fire scenarios for office building is predicted to be suppressed by the sprinkler system.

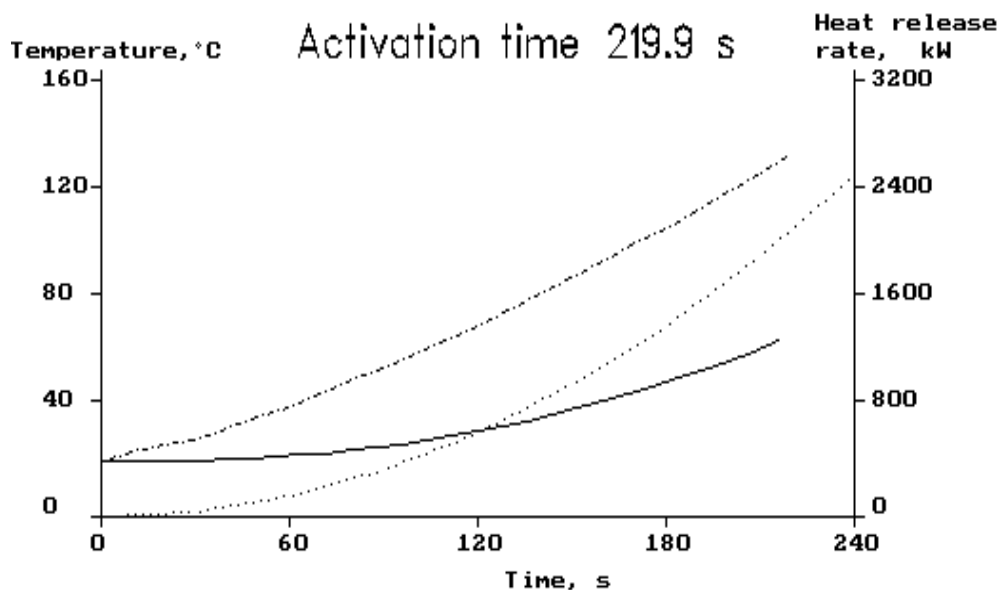
The modelled scenario is based on sprinklers located on a ceiling 2.7m above the floor level. Standard response sprinklers (RTI of  $150 \text{ m}^{1/2}\text{s}^{1/2}$ ) are placed on a typical AS 2118 OH spacing grid of 3 m x 4m. The modelled sprinklers have a temperature rating of 68°C. A FAST ( $k=150$ ) fire growth rate has been assumed.

In line with the Fire Engineering Guidelines (Ref 13) the fire is modelled as a suppressed fire using the NIST suppression curve. The fire is assumed to be suppressed commencing at the time of the second closest sprinkler head activating. Thus the distance to the head from the fire is 4.9m

The results from Firecalc's "Sprinkler" module are shown below:

Height of ceiling above fuel 2.7 m  
Distance of detector from axis of fire 4.9 m  
Initial room temperature 21 °C  
Detector Actuation Temperature 68 °C  
Detector Response Time Index (RTI) 150  $\sqrt{\text{m.s}}$   
The smallest detectable fire intensity is 564 kW

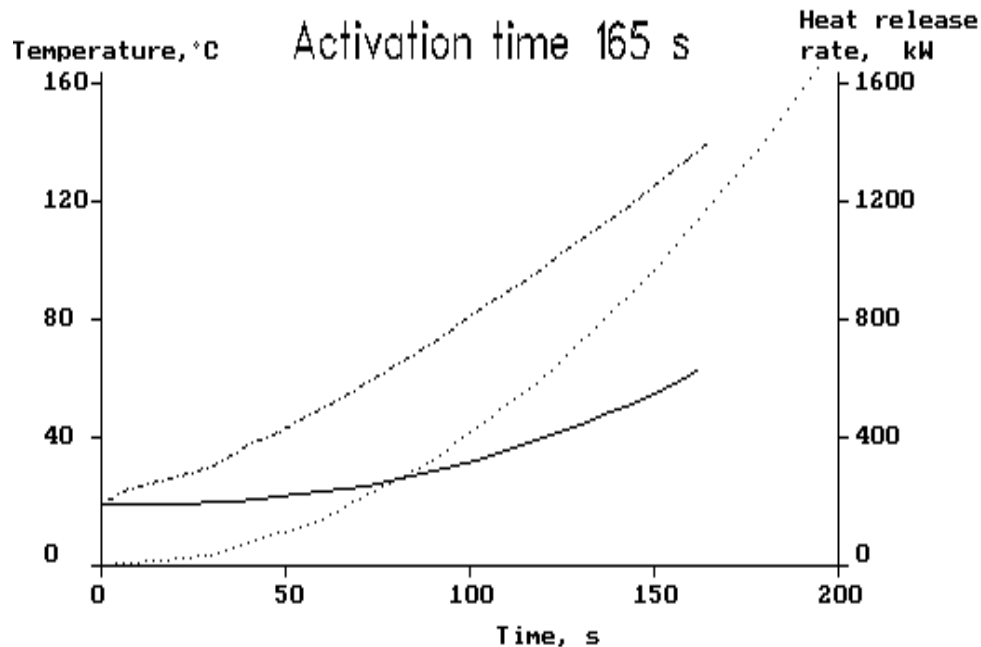
..... Heat release  
Temperatures:  
..... Air flow  
———— Detector



The above graph shows a sprinkler at a 4.9m distance from the fire (ie likely to be the second head operating), in order to give a conservative estimate of likely maximum fire size prior to extinguishment.

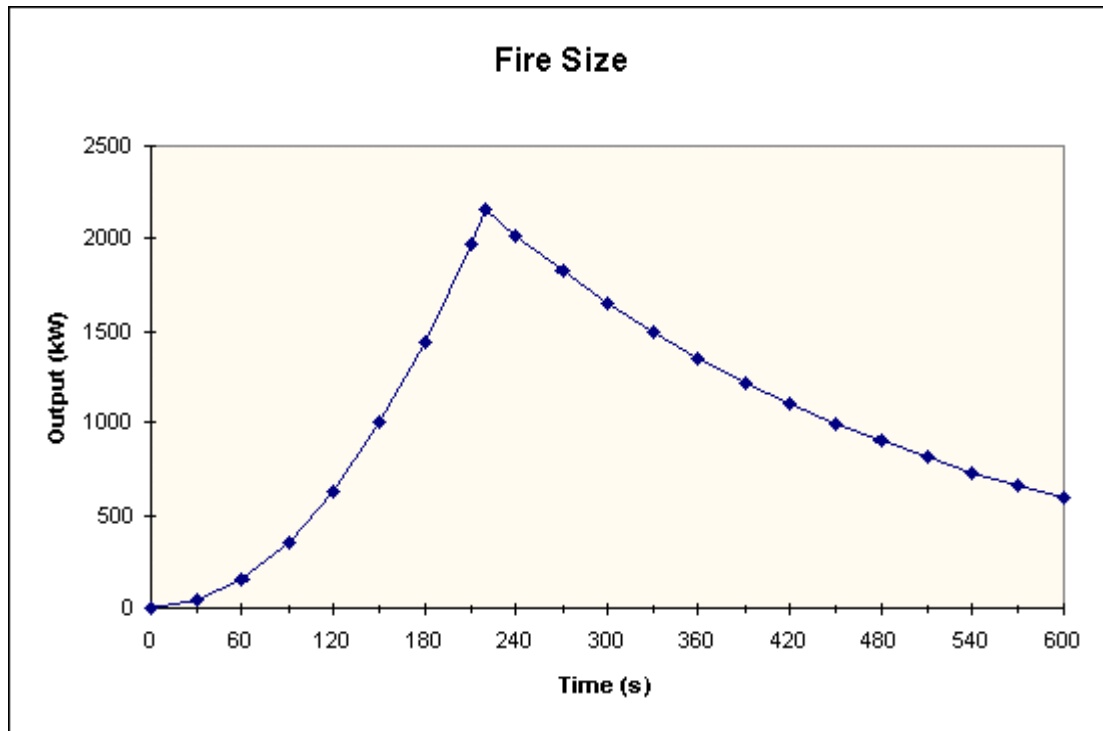
Height of ceiling above fuel 2.7 m  
Distance of detector from axis of fire 2.5 m  
Initial room temperature 21 °C  
Detector Actuation Temperature 68 °C  
Detector Response Time Index (RTI) 150  $\sqrt{\text{m.s}}$   
The smallest detectable fire intensity is 288 kW

..... Heat release  
..... Temperatures:  
..... Air flow  
..... Detector



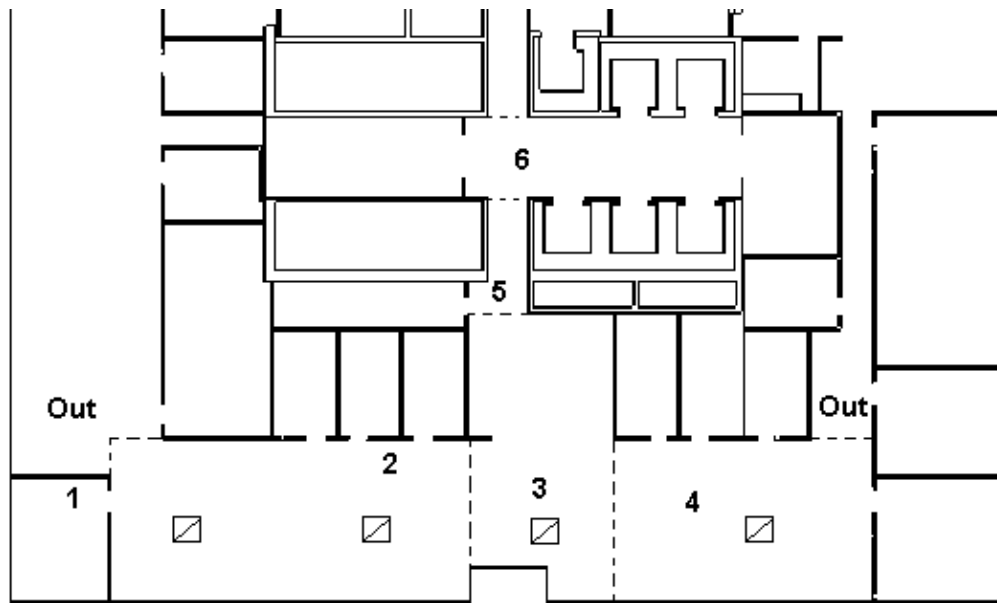
The second graph shows a sprinkler head at 2.5 m distance from the fire, in order to give an estimate of the likely time of operation for raising an alarm to initiate evacuation and signal the lift installation to recall to the main entry level.

Thus, with the sprinkler activation time at 220 s the NIST suppression curve is used to generate the modelled fire heat output profile v time curve. The modelled curve is presented below.

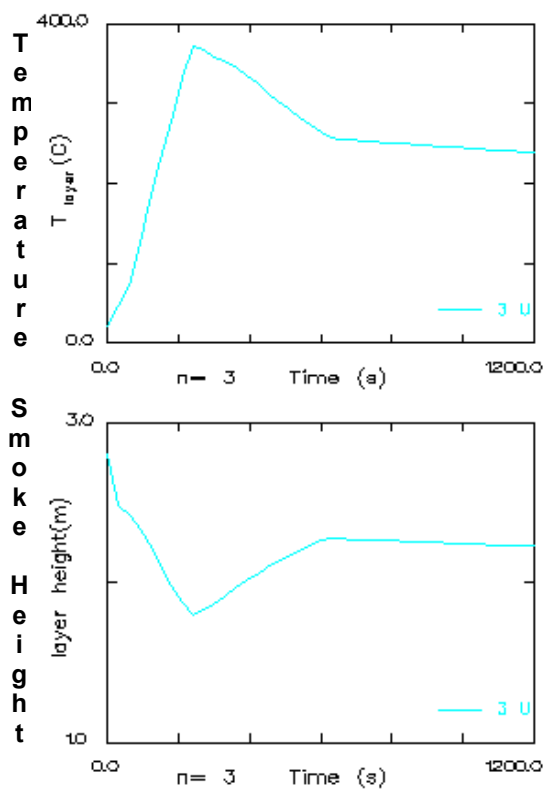


The above design fire is then used in Hazard (Ref 15) to calculate the hot layer temperature and interface height. The Hazard model definition and input parameters have been presented in Appendix 3. Hazard is a zonal model which assumes that the smoke forms a distinct layer at the ceiling. This hot layer sits on top of a cool layer which essentially remains at ambient conditions. The height above the floor level to the bottom of the hot layer is called the interface height. The model is based on the fire in compartment 3 (open to compartments 2, 4, & 5) and the lift lobby is modelled as compartment 6 (separated by a closed door without smoke seals). These are the two critical compartments in terms of occupant tenability.

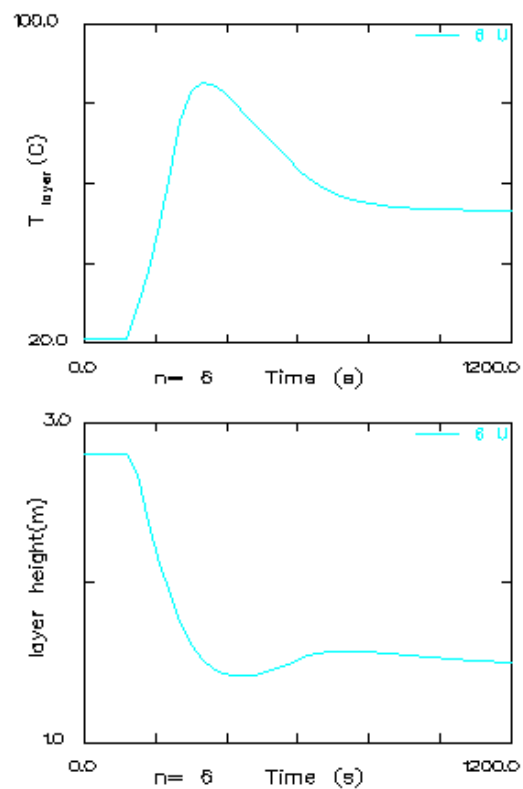
The results for hot layer temperature and interface height are shown in the layout below.



Conditions in Zone 3



Conditions in Zone 6



## Modelling Results

The results based on conditions arising from sprinklers at 4.9 m radius from the fire indicate that the open space (compartment 3) becomes untenable very quickly. This, however, contradicts experience from real tests done in the past. For this reason the analysis of the fire scenario using computer models was not continued and full scale fire tests were carried out as defined in the following sub-section.

In reflection on the computer based analysis, having undertaken the full scale testing, it is worth noting that the temperature readings in the area close to the fire in the full scale test are similar to that of the fire compartment in the computer model. Thus the computer model is predicting the temperature peak of the hot layer but not the cooling effects as it spreads away from the source.

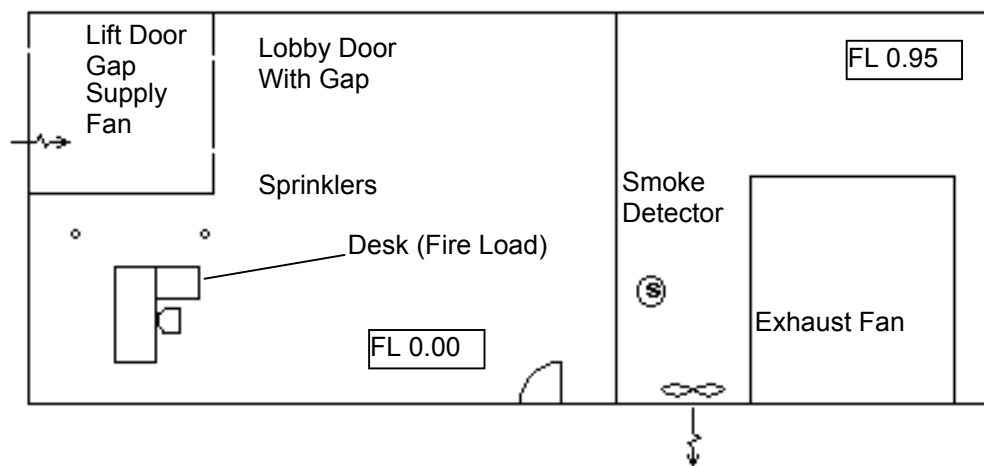
## 9.2 FIRE TESTING

In addition to the computer fire modelling, full scale fire tests were carried out at the test rig at BHP Melbourne Research Facility. This testing investigated the development of a fire in a typical office and the temperatures of the smoke layer achieved given the postulated designs for maintaining safe evacuation.

The purpose of this research study, and thus the fire and smoke analysis, is to assess the evacuation of people with disabilities in sprinkler protected building. The design options which are considered are the use of the elevators for evacuation and/or the construction of places of refuge. Therefore, regardless of the design intent, there will be a period in which both people with disabilities and people without disabilities will need to egress from the immediate vicinity of the fire. The key time events to analysis is the period between sprinkler operation and approximately 10 - 15 minutes after when people have reached either a stair, lobby or place of refuge as applicable. A fundamental variable to be considered in regard to using lifts is the predicted conditions in the lobby during this period.

### 9.2.1 Test Rig

The Fire Test is designed to replicate a typical office space and a possible construction of a lift lobby so that a visual assessment of the proposed designs under fire conditions can be made. The lobby is a plaster board construction with the door modelled with a sheet of plasterboard with a gap of approximately 10 mm around to simulate no smoke seals.



**Test Rig Layout**

Thermocouples are located on the ceiling at varying distances from the fire source and also in the "Lift lobby". There are also thermocouples located at 1 m from the floor (approximate head height of a person in a wheelchair) both inside the lobby and just outside the door. The sprinklers are positioned as Light Hazard spacing to approximate the worst case scenario. The results for both test scenarios are presented in Appendix 4.

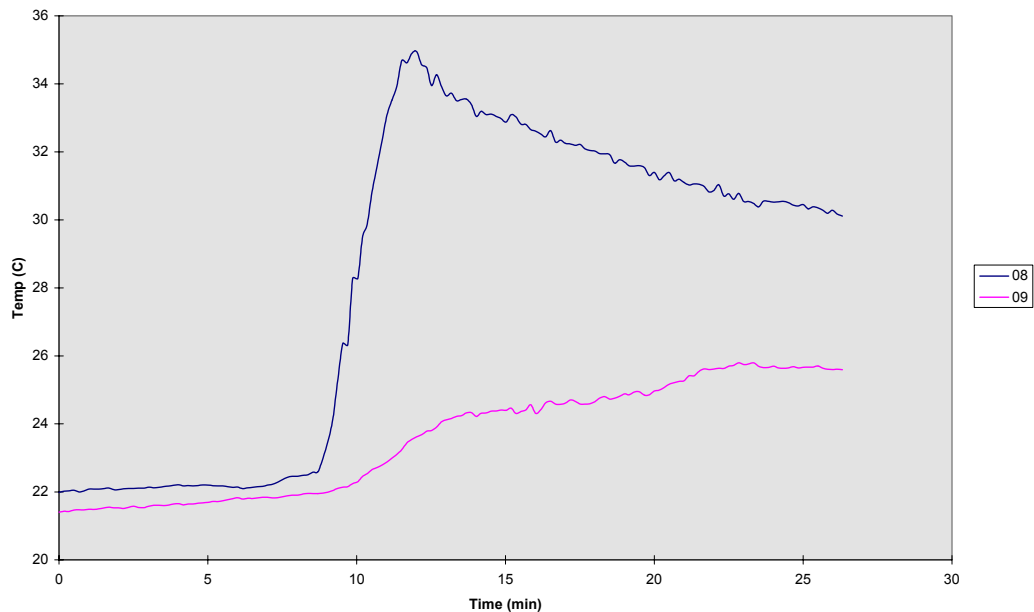
It is important to note that in both tests carried out there was no water in the lobby at the end of the test after approximately 25 minutes.

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### 9.2.2 Test 1

The objective of the first fire test is to assess the appropriate construction of the lobby. The test assesses the effectiveness of light weight construction. If a lobby is shown to be safe for the period of egress, a lobby is a more reliable option as occupants would be familiar with the lobby but are unlikely to be familiar with the location of a place of refuge.

Observations of Test 1 showed that a lightweight construction, given sprinkler operating as anticipated, provided sufficient separation in terms of fire and heat. The temperatures in the Lift lobby did not exceed 35°C at ceiling level and 26°C at 1m from the floor. This is well within the tenable limits of occupants.



However, as can be seen in the above photo, significant quantities of smoke entered the lift lobby.

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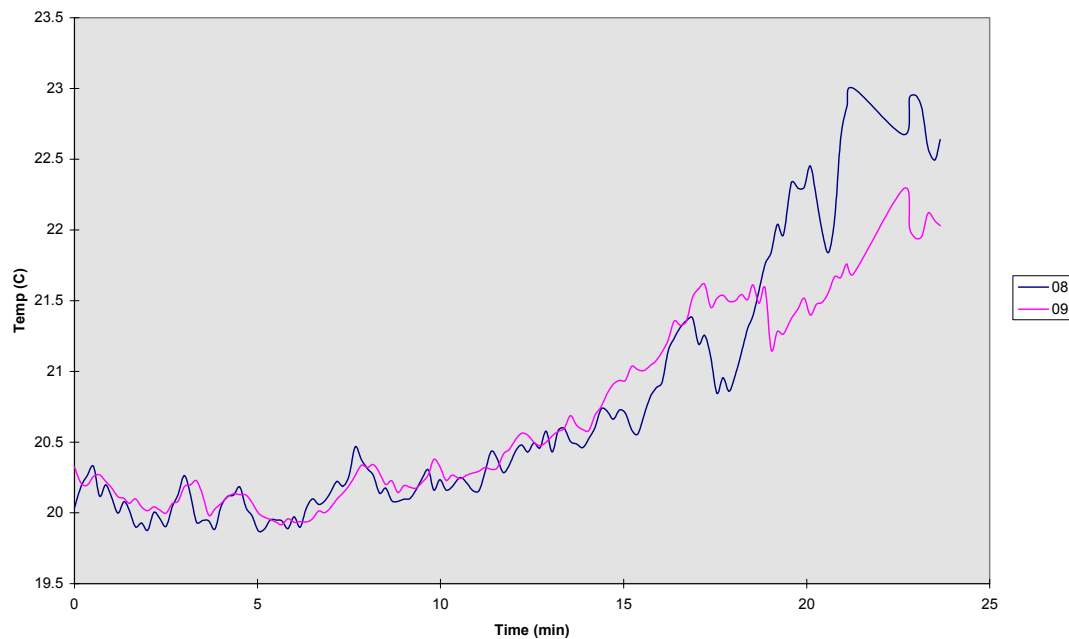
The result of this test was that, while conditions in the lift lobby were unlikely to be life threatening, the level of smoke in the lobby may cause panic to the waiting occupants.

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### 9.2.3 Test 2

Test 2 looks at the effects of smoke management systems including the exhaust of smoke from the floor and the pressurisation of the lobby. The test scenario includes smoke detection to initiate exhaust fan and lobby pressurisation after a time delay. This has a level of conservatism in that, during the normal hours of building operation, the return air system will be expected to be operating and thus the smoke layer will descend more slowly.

The results of Test 2 show that the temperatures fluctuate slightly in the lift lobby but essentially remain unchanged from ambient conditions. The marked difference in comparison to Test 1 is that there was little to no smoke present in the Lift lobby.



Thus, this test showed that the lightweight construction of the lift lobby coupled with the introduction of a pressure difference between the lobby and the open space provided tenable conditions for an indefinite period of time. Thus the lobby could be used safely to hold people with disabilities until a lift arrived. In addition people who were in the lift would not be put at risk by smoke entering the car.



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### 9.3 EVACUATION SIMULATION

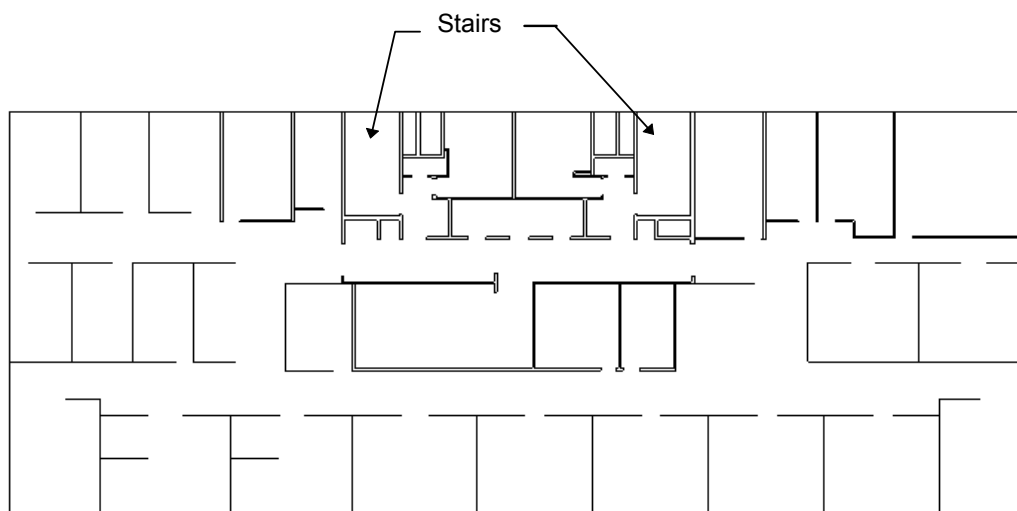
Evacuation simulations have been carried out using buildingEXODUS to assess the trial design scenarios. These results are then compared to the simulated fire scenario to assess the life safety of the occupants. Two typical office floor plates have been modelled.

### 9.4 CASE STUDIES

#### 9.4.1 Case 1

Case 1 has been modelled with a population of 100 people on a typical floor of 1000 m<sup>2</sup> area. It has been assumed that 6% of the population is disabled and are randomly distributed around the floor. The model has been run several times to allow for the different starting locations of the people.

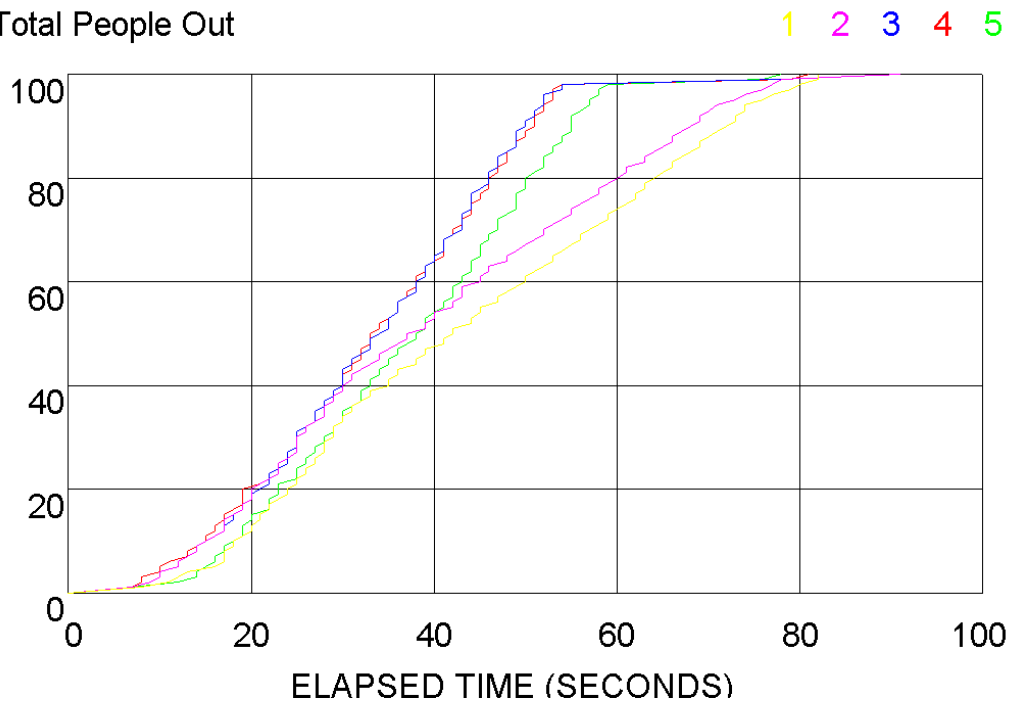
In defining the characteristics of people with disabilities it has been assumed that the mobility of the occupant is 30% of an average able person and an additional 30 seconds has been added to the reaction time.



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As can be seen by the results of the five runs (numbered 1-5 in the graph below), the movement time varies between about 75 and 90 seconds.

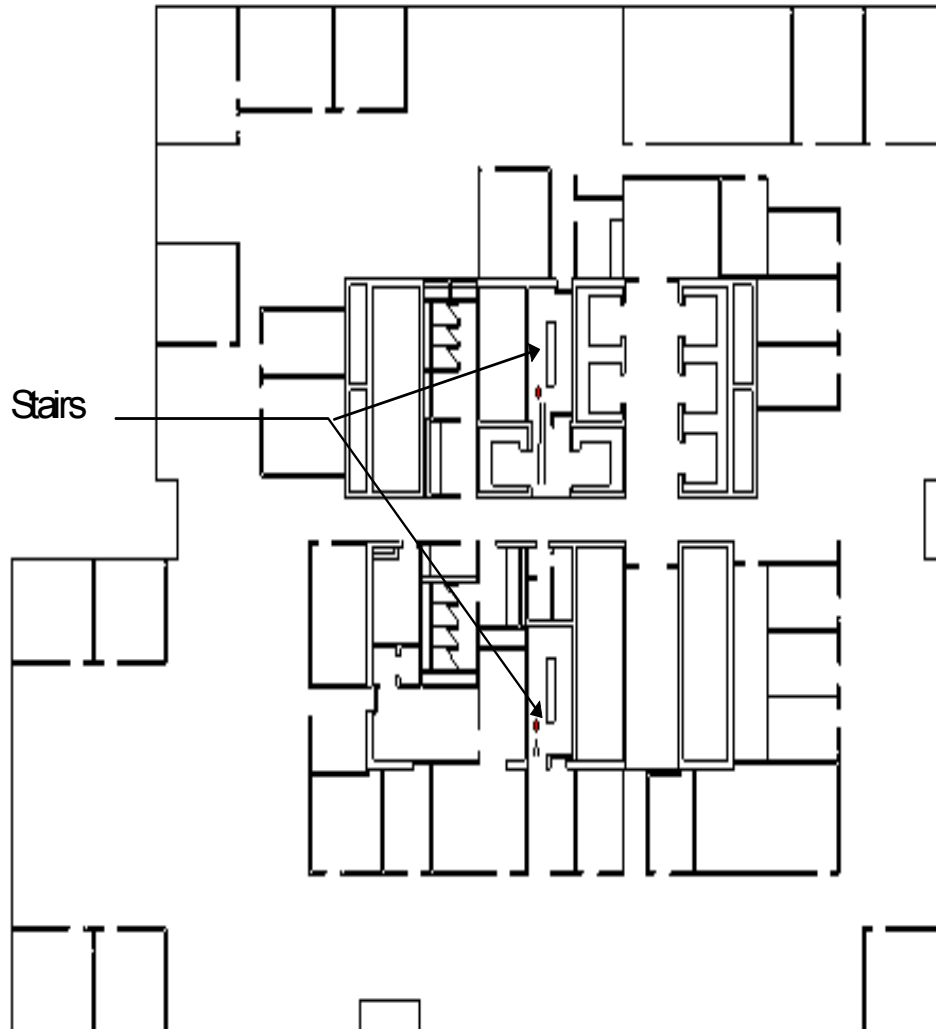
Total People Out



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#### 9.4.2 Case 2

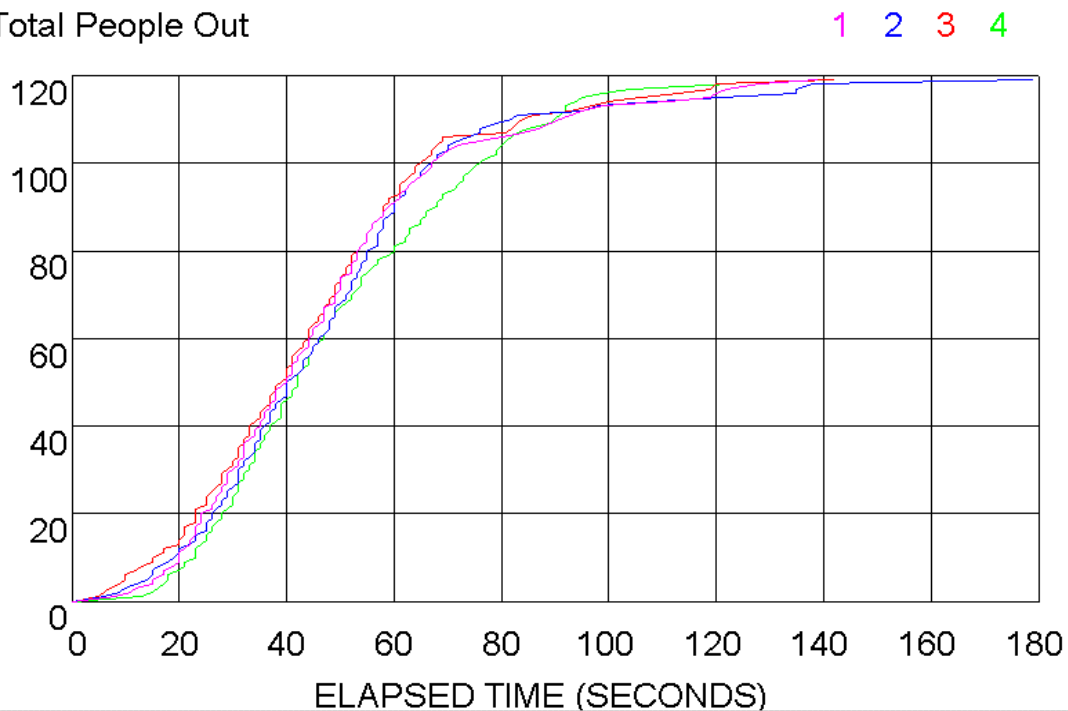
The evacuation modelling in Case 2 was carried out on a typical floor plan of 1200 m<sup>2</sup> as shown below. In this scenario, a population of 120 was used for evacuation calculations. In this case, a worst scenario of 8% of the occupants were modelled as people with a disability.



The results indicate that the larger percentage of people with disabilities tends to give a larger range of evacuation times. This can be related to the starting locations of the occupants with a disability.

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Total People Out



#### 9.4.3 Evacuation results

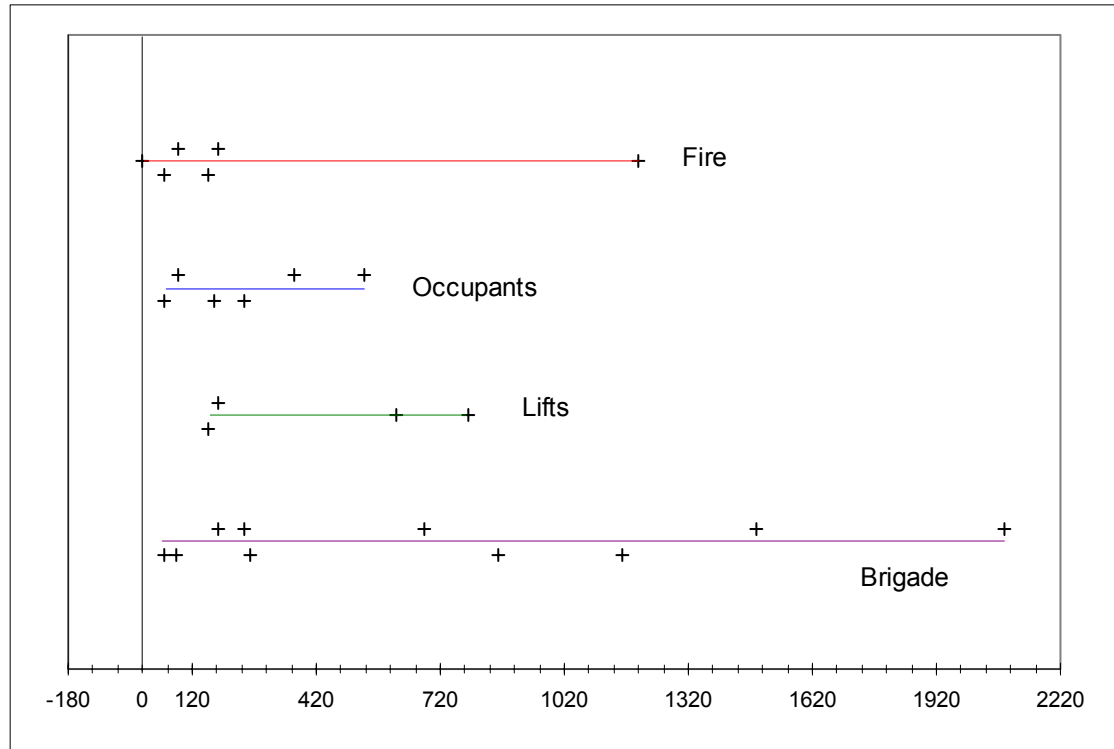
The egress modelling results indicate that the movement time for floor evacuation is in the order of two to three minutes. The response time for the occupant will vary depending upon their proximity to fire related cues (ie sensing fire or smoke). In an office environment the occupants are expected to be alert. Therefore without the presence of fire related cues, at a maximum, the response time is expected to be in the order of three minutes. Thus the total evacuation time will be in the order of six minutes after the detection time.

In comparison to the time line of the fire testing, occupants are expected to have sufficient time to evacuate safely. This however is based on the assumption that all occupants react at approximately the same time. Occupants close to the fire will benefit from the direct fire cues and react sooner. Thus people at a higher risk will tend to evacuate earlier.

# 10. DISCUSSION

## 10.1 MODELLING RESULTS

The timelines below summarise the theoretical modelling of the study. As the results have a range the times are indicated as a probable minimum and maximum. Minimums are plotted below the line and maximums are above.



The key times represented in the chart above are tabulated below.

Description	Time	Description	Time
Fire Growth	0 s	Response max	365 s
Smoke Detectors min	51 s	Evac max	535 s
FB Alarm min	81 s	Disabled Evac	612 s
Smokes Detectors max	88 s	FB Arrival max	683 s
Sprinkler OH	160 s	Disabled Evac 4 Lv's	786 s
Response min	171 s	FB Setup min	861 s
Sprinkler LH	185 s	FB Extinguishment min	1161 s
FB Alarm max	245 s	Suppression	1200 s
Evac min	246 s	FB Setup max	1483 s
FB Arrival min	261 s	FB Extinguishment max	2083 s

## 10.2 DUPLICATE STAIRS

The findings of the study could lead to a conclusion that the current requirement for two egress stairs could change to require only one stair.

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The requirement for a minimum of two stairs appears to be based on the concept of avoiding a 'single point of failure' or provision of redundancy.

Whilst some building layouts, produced within present requirements do have a 'single point of failure', moving to remove the present requirement for a minimum of two stairs is expected to need the following:

- Proven performance, under simulated emergency conditions, of the lift and people management regimes, necessary to confirm that evacuation by lifts provides repeatable, reliable performance,
- Recognising that services supporting lift operation should have the same level of reliability of other 'links in the safety chain'. In essence, this would require a power supply of similar reliability to say, sprinkler water supplies. This is already achieved in many prestige buildings, through the provision of emergency generators,

This discussion does not indicate that lifts need always be provided with emergency power if they are to be utilised for evacuation. On a basis of probability, the likelihood of a cumulative power failure and a fire of the size likely to cause sprinkler operation is extremely low.

### **10.3 BCA PROVISIONS**

The present BCA provisions, particularly for technology installations such as lifts, deal with each installation substantially in isolation from other such installations, ie fairly much on a "trade by trade" basis. The BCA is focussed on design and construction issues, with little present reference to the role of commissioning and operational issues in achieving target outcomes. In addressing a time dependent matter, such as evacuation under emergency conditions, little guidance is presently provided. It is likely that a greater understanding of "performance" will eventually change this situation. None the less, the study has identified some aspects relating to the design and construction of lifts which would require regulatory change should the outcome of the study proceed to implementation.

### **10.4 BUILDING FABRIC**

The BCA presently aims to protect lift installations from the effects of fire. As lifts are presently barred from use, apart from by Fire Services personnel, the present requirement has, as a main target consequence, a limitation on the spread of fire from floor to floor. The study identified that fire spread in sprinklered buildings is improbable but that the present requirements may not achieve management of the spread of smoke via lift shafts. Protection of lift shafts from threat of smoke spread, via the use of lift lobbies as a barrier would appear to have considerable merit. Management of airflows, to support the physical barriers provided by lift lobbies would appear to be necessary to achieve protection from smoke spread. Pressurisation of lift shafts can provide pressurisation of lobbies, but pressurisation is not necessarily the most cost effective solution, particularly where a pressurised stair opens into a lift lobby. Earlier studies had identified that operation of lifts is unlikely to be adversely effected by smoke management measures and that lift operation (the piston effect) was not likely to adversely effect smoke hazard management solutions.

### **10.5 DESIGN POPULATION**

The BCA does not directly require a particular performance for lifts. The nominal population for office buildings, 1 person/10 square metres noted in the BCA is significantly greater than that normally used for lift design and significantly greater than that measured in practice. For comparison the replies to the building manager questionnaire indicated the average occupancy level was 1 person/19m<sup>2</sup> (with the minimum 1/9m<sup>2</sup> and the maximum at 1/39m<sup>2</sup>). Thus, the value used in the BCA seem to be within the correct order of magnitude but over estimates actual occupancy levels.

Experience gained undertaking design and documentation of some 500,000m<sup>2</sup> of tenancy fitout work indicates a value of 1/15m<sup>2</sup> although some organisations are now actively working to reduce this ratio.

Denser populations than this value are seen as highly unlikely, particularly if net lettable areas are used. Conservatism increases if gross floor areas are used in analysis and design calculations.

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Actual occupancy levels are generally less than design levels due to people attending to business outside the office, annual leave and sick leave. Annual leave and sick leave alone are likely to result in a 15% reduction in density. Work practices and the nature of business conducted can reduce actual occupancy rates to some 50% of the number of work stations or seats provided.

Using 1/10m<sup>2</sup> would result in a very conservative value for use in assessment of office buildings. It could easily be twice the actual value of normal occupancy patterns but allows for intermittent attendances for occupancies serving the visiting public.

A percentage of people on a typical office floor can be expected to have a disability. However, it is difficult to define a fixed number as it fluctuates markedly between buildings, businesses and times of day. Statistics on both the general population and the population of people with disabilities within the work force provide a perspective that a design population of people with disabilities can be based upon.

The statistical outcome of the study was that while the general population has an occurrence of people with disabilities of 18%, the percentage in the work force is much lower. While it is conceivable that particular scenarios may have a larger concentration of people with disabilities, an upper mean value, considered appropriate to the design and management of office buildings, is 6% of the overall office population. In the event where the population of people with disability is greater than the 6% additional measures may be required to provide appropriate safety.

It is noteworthy that only a portion of the 6% will be mobility or audibly impaired and that building solutions relying solely on physical planning and building systems, as distinct from those embracing an effective information systems and management plans, are less likely to be efficacious. Such plans are contemplated by the DDA and have relevance in the context of establishing safe egress.

For the purposes of the study a population of density of 1 person per 10 square metres with 6 % of that population being people with disabilities was used to predict a time line for evacuation using lifts. Due to the highly conservative value used for population density, the results are considered highly conservative.

## **10.6 EXISTING BUILDINGS**

The Regulatory impact study into the potential benefits and costs of measures aimed at increasing accessibility for people with disabilities provides excellent insight into the comparison of the effects of regulatory change on new buildings compared to existing building stock. That study assumed a refurbishment cycle of 20 to 25 years, with all of the existing building stock being captured during that period. In practice, it is likely that the rate of capture of "retrospectivity" will be greater. Even at that rate of application, the community expenditure required to implement the measures was of the same magnitude for the existing building stock as for new buildings. As a consequence, the study placed emphasis on the feasibility of implementation of measures investigated for both existing and new buildings.

This issue has particular relevance in regard to protecting lift installation components from the threat of water from sprinkler installations and fire fighting operations.

## **10.7 AUTOMATIC RECALL**

In order to maximise the availability of lifts, as a resource which might be used to support emergency management activities, the simple measure of having lifts automatically recalled to a common floor is expected to be of significant value. It is understood that automatic recall is required in some overseas jurisdictions already.

Where "Firemans Recall" is fitted to all lifts, as is the case with many recent lift installations, an additional parallel control, sourced from the fire detection system is likely to be an inexpensive, simple measure to adopt.

Adoption of automatic recall will involve consideration of a number of issues:

- What signal initiates the recall ?

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- If lifts are recalled, how do building emergency management staff reach the common location to manually manage the lifts?
  - What information systems are in place, to summon the building emergency management team, to inform people in the lifts what is going on, to communicate to the building emergency management team whether it is safe to travel back to the floor on which the fire alarm has been registered ?

Adoption of automatic recall can provide a simple means of avoiding an existing potential problem, in that presently people can enter a building and travel to a floor on which an alarm has been registered, without any knowledge of the risks they might face and possibly adding to the burden of subsequently managing their evacuation.

## **10.8 MANAGEMENT AND TRAINING**

Adoption of lifts as a resource for use in emergencies, on the assumption that lifts can be physically protected from fire, smoke, water and power reliability threats, will involve a significant effort in communication, training and 'relearning'. For instance, the subliminal message from years of seeing "Do not use this lift in the event of a fire" is a significant barrier to reverse. How do the public know if they are in a sprinkler protected building or not?

On the other hand, the normal behaviour of people is to exit a building the way they entered. Often egress stairs are in unfamiliar locations and are uninviting places that once entered are not possible to get out of until the final exit, at ground level is reached.

All of these issues will need to be addressed through training and the building emergency management procedures and team actions, if lifts are to be utilised as a resource in emergencies.

The lift industry will need to be involved in such training and communication.

Building Emergency Management teams and Fire Service personnel can benefit from a better understanding of how lifts operate and how to gain the most benefit from operation in emergencies.

Integration of communication facilities into lifts, to better inform occupants of what is going on under emergency management conditions and as an emergency management tool are expected to be of considerable benefit in achieving effective outcomes for all participants.

## **10.9 THREATS TO LIFT RELIABILITY**

The study indicated that the threats to lift operation presented by fire and smoke are capable of being managed.

The threat presented by water, from sprinkler discharge or fire fighting activities, is time variant. In the period prior to Fire Service arrival, only water from sprinklers is likely to be a threat. A range of simple techniques to manage this threat would appear to be available. Such techniques are expected to provide protection of the lift shaft for at least 20 minutes for water discharges on typical floors. Access to information as to where water is being discharged and at what rate (both of which can be sourced from modern building information systems) will assist in managing the threat due to water. In essence, managing the water threat by undertaking measures external to the lift shaft is seen as achievable, but added protection to possible users of lifts during a fire emergency, by better access to information, is a worthwhile tool. In view of the extent of existing installations, the physical and economic feasibility of protecting lift shaft systems from water is not seen as sustainable.

The threat presented to power availability is ever present. Whilst many high rise buildings are equipped with on site emergency power, not all buildings are. Where on site emergency power is installed and treated as part of the "essential services" installation, routine verification of the ability of such power supply to close to the lift supply and subsequently operate lifts is seen as providing a level of reliability commensurate with community expectations as expressed in the BCA. Where multiple sources of external power supply are present, a similar testing and verification technique is seen as providing the same outcome.



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Where the power supply to lifts is sourced from a single external supply, the likelihood of external failure occurring coincident with a fire needs to be considered, on the assumption that supply is not compromised by fire fighting activities. Such compromise is not likely in the initial stages of a fire incident.

The rate of power supply failures will vary depending on the policies of the distribution and retailing organisations. Whilst reliability of power supply is not yet regulated, increasing competition of energy providers and increasing involvement of regulators is likely to result in a higher level of predicability of power supply reliability.

Typical power failure rates in urban Australian locations, where high rise buildings are likely, can be taken to approximate 3 number outages of 10 minutes duration per annum, ie a failure rate of  $5.7 \times 10^{-5}$  per annum. Typical high rise building fires are extremely rare, and those that extend beyond the room of fire origin ( ie likely to threaten a lift power supply ) are vary rare indeed. If a rate of 1 such fire every 20 years is utilised ( a conservative value ) , then a probability of  $5 \times 10^{-2}$  fires per annum would result. The combined probability of a fire combined with a power outage  $2.8 \times 10^{-6}$  per annum would result. Acceptance of risks at this level are quite common in the community.

#### **10.10 STUDY FINDINGS**

Sprinkler protected high rise office buildings are a special case. The combination of occupant characteristics ( awake, reasonably familiar with access / exit routes), and potential for regulation of the building management regime ( duty of care ) means that a number of simplifications to the study of emergency egress can be made. The findings therefore have relevance but are not immediately and directly applicable to other classes of buildings.

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# 11. CONCLUSIONS

The study into the feasibility of using Lifts for evacuating High Rise Sprinkler protected Office Buildings confirmed that use of lifts as a resource under emergency conditions is feasible. The implementation of such use can be achieved without significant change to present design and construction practice as far as lift installations are concerned.

Implementation of use of lifts for service under emergency conditions will necessitate adoption of a range of measures to protect lift shafts beyond what is presently required and the adoption of a wide range of training and management changes. If lifts are to be called into service in an emergency role, the physical protection, lift operational availability and operational procedures are expected to form part of the “essential services” invoked by the BCA for the buildings concerned. In a general sense, as lifts provide the only means of access to upper levels of buildings for the mobility impaired, they are already an “essential service”. Such extended definition will have lift maintenance contract implications.

Some specific conclusions are:

- a) The rate of death or injury in sprinkler protected buildings is low, to the point where it is comparable to a wide range of involuntary risks faced by members of the community in everyday activities.
- b) Threats due to smoke are considered the major consequence of fire in sprinkler protected buildings.
- c) The need to achieve complete egress of the occupancy of a high rise building in the event of fire, is not well established.
- d) The extent and quality of management of evacuation procedures presently existing is less than appropriate to support the safe evacuation of people with a disability.
- e) The achievement of safe egress from the location of a fire in a sprinklered building is most significantly influenced by the level of information provided to occupants and their level of training in response to such information.
- f) The adoption of a ‘smoke protected’ lift lobby as an intermediate point in the evacuation route for occupants with disabilities (and potentially the able) is seen as a preferable alternative solution to dedicated places of refuge in sprinkler protected buildings. A desirable arrangement would be to have such lift lobbies link to a fire egress stair.
- g) Well designed high rise building lift systems have the capacity to provide for evacuation of the complete population of one floor in approximately 5 minutes. The disabled population can egress in lesser time. Typically, lift control systems are not arranged to provide for use of lifts to evacuate. Rearrangement of controls is feasible and considered to be economically achievable.
- h) Threats to lift system operation under fire conditions in a sprinklered building can be managed to the point where operation under fire conditions is as reliable as most aspects of a building’s safety features. Such reliability is time variant and reduces as the period of sprinkler discharge increases.
- i) Threats due to smoke to lifts and a lobby adjacent to the lift capable of accommodating the likely population of people with disabilities on a typical floor can be managed to a level commensurate with any other aspect of a building’s safety features.
- j) The likely cost and extent of works to achieve management of threats to lift operation and smoke hazard to evacuees are modest and seen as capable of implementation in the course of normal refurbishment, the basis on which the ABCB Regulatory Inspection Statement on RD97/01 was prepared.
- k) Existing management responsibilities for evacuation processes are not clearly defined. Implementing an evacuation management plan which references stairs for the abled and either lifts or places of refuge for

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the people with disabilities is seen as not aiding the achievement of a clear set of actions under stress conditions.

- l) In sprinkler protected buildings, the propensity of fire to spread, to the point where egress is compromised, is low for both the able and people with disabilities.
- m) Sprinkler protection provides a measure of smoke hazard management, insofar as the source of smoke is controlled. There is no common smoke hazard management regime throughout the existing building stock. The study findings, insofar as the treatment of lift lobbies was concerned, was that airflows of the magnitude typically available in high rise buildings provided management of the lift lobby smoke hazard. If the lift lobby is directly connected to a stair equipped with a 'pressurisation' system compliant with BCA 96, the air flow into the lobby when the stair door is open, is likely to be more than sufficient to manage smoke hazard in the lobby.
- n) Fire Brigade intervention, to the point of controlling a fire in a high rise sprinklered building, is likely to be at a time:
  - o) when the floor concerned has been evacuated
  - p) when the fire is controlled by the sprinklers.
- q) The role of the Fire Brigade in relation to management of evacuation is less than clear. Existing Australian Standards contemplate that the initial responsibility for management of evacuation lies with the building emergency management team. Protocols for hand-over of responsibility for management of evacuation are not clear.
- r) It is desirable to harness what knowledge occupants have of a building and in commonly used circulation paths, to facilitate way finding.
- s) The threats to lift operation under fire conditions and due to fire, smoke or water can be managed during the likely period of egress using lifts. Such management can be achieved through a combination of ramping at lift lobby doors to contain water discharge and lobby 'pressurisation' as noted previously.
- t) Communication, of nature of threat and actions required to avoid it, are key tools in achieving safety in buildings. Communication to both the able and people with a disability is appropriate. Specific provisions for people with disabilities will assist, particularly a combination of communication and management achievable through a 'buddy' scheme

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# **APPENDIX 1**

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**Evacuate the Fire Floor ONLY (1 Level) - Only Disabled Evacuees via Lifts**

People per floor is 120.  
Distance between floors is 3.80 m or 12.47 ft.  
Elevator usage percent is 6.000%  
Normal car velocity is 2.50 m/s or 492.13 fpm.  
Car acceleration is 1.00 m/s<sup>2</sup> or 3.28 ft/s<sup>2</sup>.  
Car full load is 3 people.  
Full load standing time is 18.63 s.  
Other transfer inefficiency is 0.0000  
Trip inefficiency is 0.100  
Door type: F Center-Opening 1100mm (42in) wide  
Doortime s 4.600 Door inefficiency 0.050

Floor Name	Elevation m ft		One Way Time s	Round Trip Time s	People on Floor	Percent Usage	Round Trips	Time per Floor s
12	46.8	153.5	21.8	61.1	0	6.0	0	0.0
11	43.0	141.1	20.3	58.1	0	6.0	0	0.0
10	39.2	128.6	18.8	55.0	0	6.0	0	0.0
9	35.4	116.1	17.2	52.0	0	6.0	0	0.0
8	31.6	103.7	15.7	50.1	120	6.0	3	149.1
7	27.8	91.2	14.2	45.9	0	6.0	0	0.0
6	24.0	78.7	12.7	42.9	0	6.0	0	0.0
5	20.2	66.3	11.2	39.8	0	6.0	0	0.0
4	16.4	53.8	9.6	36.8	0	6.0	0	0.0
3	12.6	41.3	8.1	33.7	0	6.0	0	0.0
2	8.8	28.9	6.6	30.7	0	6.0	0	0.0
1	5.0	16.4	5.0	27.5	0	6.0	0	0.0
G	0.0	0.0						

Total round trip time=	149.1
Start up time=	300.0
Time to get to the outside after leaving the elevator=	30.0
Evacuation time using 3 elevators=	384.7
(or 6.4 minutes)	

**Scenario:**

- The fire occurs on the 8<sup>th</sup> floor.
- Only the fire floor is evacuated (floor 8).
- The fire floor has a NRA of 1,200m<sup>2</sup>. Assumed population density is one person per 10m<sup>2</sup>.
- The floor is served by 4 lifts, but one is assumed to be unavailable due to it being used by the fire service, thus 3 lifts are used for evacuation.
- Only people with disabilities are evacuated by lifts. All others evacuate via stairs.
- 6% of the population on each floor are assumed to be people with disabilities.
- Time required for building management to respond and to commence transferring people in lifts, is five minutes (300 sec).

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**Evacuate Fire Floor ONLY (1 Level) - All Evacuees Via Lifts**

People per floor is 120  
Distance between floors is 3.80m or 12.47 ft  
Elevator usage percent is 100.000%  
Normal car velocity is 2.50 m/s or 492.13 fpm.  
Car acceleration is 1.00 m/s<sup>2</sup> or 3.28 ft/s<sup>2</sup>.  
Car full load is 10 people.  
Full load standing time is 29.44 s.  
Other transfer inefficiency is 0.0000  
Trip inefficiency is 0.100  
Door type: F Center-Opening 1100mm (42in) wide  
Doortime s 4.600 Door inefficiency 0.050

---

Floor Name	Elevation m ft		One Way Time s	Round Trip Time s	People on Floor	Percent Usage	Round Trips	Time per Floor s
12	46.8	153.5	21.8	61.1	0	100.0	0	0.0
11	43.0	141.1	20.3	58.1	0	100.0	0	0.0
10	39.2	128.6	18.8	55.0	0	100.0	0	0.0
9	35.4	116.1	17.2	52.0	0	100.0	0	0.0
8	31.6	103.7	15.7	60.9	120	100.0	12	730.8
7	27.8	91.2	14.2	45.9	0	100.0	0	0.0
6	24.0	78.7	12.7	42.9	0	100.0	0	0.0
5	20.2	66.3	11.2	39.8	0	100.0	0	0.0
4	16.4	53.8	9.6	36.8	0	100.0	0	0.0
3	12.6	41.3	8.1	33.7	0	100.0	0	0.0
2	8.8	28.9	6.6	30.7	0	100.0	0	0.0
1	5.0	16.4	5.0	27.5	0	100.0	0	0.0
G	0.0	0.0						

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Total round trip time= 730.8  
Start up time= 300.0  
Time to get to the outside after leaving the elevator= 30.0  
Evacuation time using 3 elevators= 598.0  
(or 10.0 minutes)

**Scenario:**

- The fire occurs on the 8<sup>th</sup> floor.
- Only the fire floor is evacuated (floor 8).
- The fire floor has a NRA of 1,200m<sup>2</sup>. Assumed population density is one person per 10m<sup>2</sup>.
- The floor is served by 4 lifts, but one is assumed to be unavailable due to it being used by the fire service, thus 3 lifts are used for evacuation.
- All people on the fire floor are evacuated by lifts.
- 6% of the population on each floor are assumed to be people with disabilities.
- Time required for building management to respond and to commence transferring people in lifts, is five minutes (300 sec).



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**Fire Effectuated Floors (4 Levels) - Only Disabled Evacuees via Lifts**

People per floor is 120.  
Distance between floors is 3.80 m or 12.47 ft.  
Elevator usage percent is 6.000%  
Normal car velocity is 2.50 m/s or 492.13 fpm.  
Car acceleration is 1.00 m/s<sup>2</sup> or 3.28 ft/s<sup>2</sup>.  
Car full load is 3 people.  
Full load standing time is 18.63 s.  
Other transfer inefficiency is 0.0000  
Trip inefficiency is 0.100  
Door type: F Center-Opening 1100mm (42in) wide  
Doortime s 4.600 Door inefficiency 0.050

Floor Name	Elevation m ft		One Way Time s	Round Trip Time s	People on Floor	Percent Usage	Round Trips	Time per Floor s
12	46.8	153.5	21.8	61.1	0	6.0	0	0.0
11	43.0	141.1	20.3	58.1	0	6.0	0	0.0
10	39.2	128.6	18.8	56.2	120	6.0	3	167.4
9	35.4	116.1	17.2	53.1	120	6.0	3	158.2
8	31.6	103.7	15.7	50.1	120	6.0	3	149.1
7	27.8	91.2	14.2	47.0	120	6.0	3	140.0
6	24.0	78.7	12.7	42.9	0	6.0	0	0.0
5	20.2	66.3	11.2	39.8	0	6.0	0	0.0
4	16.4	53.8	9.6	36.8	0	6.0	0	0.0
3	12.6	41.3	8.1	33.7	0	6.0	0	0.0
2	8.8	28.9	6.6	30.7	0	6.0	0	0.0
1	5.0	16.4	5.0	27.5	0	6.0	0	0.0
G	0.0	0.0						

Total round trip time = 614.7  
Start up time = 300.0  
Time to get to the outside after leaving the elevator = 30.0  
Evacuation time using 3 elevators = 555.4  
(or 9.3 minutes)

**Scenario:**

- The fire Occurs on the 8<sup>th</sup> floor.
- Only the fire floor (8), two floors above and one floor below the fire floor are evacuated (floors 7-10 inclusive).
- Each floor has a NRA of 1,200m<sup>2</sup>. Assumed population density is one person per 10m<sup>2</sup>.
- The floors are served by 4 lifts, but one is assumed to be unavailable due to it being used by the fire service, thus 3 lifts are used for evacuation.
- Only people with disabilities are evacuated by lifts. All others evacuate via stairs.
- 6% of the population on each floor are assumed to be people with disabilities.
- Time required for building management to respond and to commence transferring people in lifts, is five minutes (300 sec).

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**Fire Effectuated Floors (4 Levels) - All Evacuees via Lifts**

People per floor is 120.  
Distance between floors is 3.80 m or 12.47 ft.  
Elevator usage percent is 100.000%  
Normal car velocity is 2.50 m/s or 492.13 fpm.  
Car acceleration is 1.00 m/s<sup>2</sup> or 3.28 ft/s<sup>2</sup>.  
Car full load is 10 people.  
Full load standing time is 29.44 s.  
Other transfer inefficiency is 0.0000  
Trip inefficiency is 0.100  
Door type: F Center-Opening 1100mm (42in) wide  
Doortime s 4.600 Door inefficiency 0.050

Floor Name	Elevation m ft		One Way Time s	Round Trip Time s	People on Floor	Percent Usage	Round Trips	Time per Floor s
12	46.8	153.5	21.8	61.1	0	100.0	0	0.0
11	43.0	141.1	20.3	58.1	0	100.0	0	0.0
10	39.2	128.6	18.8	67.0	120	100.0	12	803.7
9	35.4	116.1	17.2	63.9	120	100.0	12	767.3
8	31.6	103.7	15.7	60.9	120	100.0	12	730.8
7	27.8	91.2	14.2	57.9	120	100.0	12	694.3
6	24.0	78.7	12.7	42.9	0	100.0	0	0.0
5	20.2	66.3	11.2	39.8	0	100.0	0	0.0
4	16.4	53.8	9.6	36.8	0	100.0	0	0.0
3	12.6	41.3	8.1	33.7	0	100.0	0	0.0
2	8.8	28.9	6.6	30.7	0	100.0	0	0.0
1	5.0	16.4	5.0	27.5	0	100.0	0	0.0
G	0.0	0.0						

Total round trip time = 2996.1  
Start up time = 300.0  
Time to get to the outside after leaving the elevator = 30.0  
Evacuation time using 3 elevators = 1428.6  
(or 23.8 minutes)

**Scenario:**

- Fire Occurs on the 8<sup>th</sup> floor.
- The fire floor (8), two floors above and one floor below the fire floor are evacuated (floors 7-10 inclusive).
- The fire floor has a NRA of 1,200m<sup>2</sup>. Assumed population density is one person per 10m<sup>2</sup>.
- Each floor is served by 4 lifts, but one is assumed to be unavailable due to it being used by the fire service, thus 3 lifts are used for evacuation.
- All people on the fire floor are evacuated by lifts.
- 6% of the population on each floor are assumed to be people with disabilities.
- Time required for building management to respond and to commence transferring people in lifts, is five minutes (300 sec).