STUDY REPORT

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Emergency Egress – Merging Flows at Floor Stairway Interfaces

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Preface

This is a report prepared from a literature search of merging behaviour observed in trial evacuations and studies following the World Trade Center (WTC) evacuations. Validated merging behaviour and occupant behaviour in general is incorporated into egress models to demonstrate that delays in the merge process do not adversely affect egress times in the current building regulation environment.

Acknowledgments

This work was funded by the Building Research Levy.

Note

This report is intended for the Department of Building and Housing (DBH) as a technical basis for reviewing and/or updating provisions contained within their approved documents.

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Abstract

Overall building evacuation time was shown to be relatively independent of the merging flows at stairway entrances. However, the clearance rates of individual floors are greatly influenced by the respective egress flow or merge ratio from each floor.

In ideal conditions the total evacuation time of a building was shown to be primarily dependent on a critical flow through a single most restrictive point, such as a final exit of a stairwell or an exit of the building. Deference behaviour, whereby persons in merging streams offer the other the opportunity to go first, also ensures relatively even distribution between floors and stairs where people merge like a zipper. As a result the default scenario is that buildings tend to clear from the bottom up.

The problem of congestion when it does occur in real situations due to pressure in merging alone was not shown to be a contributing factor in overall egress time. In instances where congested merging occurs at the floor entrances to stairwells, it follows that stairwells will be operating at capacity downstream due to a ready supply of people waiting to use them, filling any gaps in the pedestrian traffic. Only in instances where the congestion is so bad at a floor exit that entry flow into the stairwell is restricted will there be a problem. In this case the speed of the flow already inside the stairwell is likely to increase momentarily to close gaps between people, and the “building as a whole” clearance time is unlikely to be greatly affected. Unless the stairways are not used to capacity due to upstream blockages for significant periods then the flow out of a stairwell may reduce.

In reality such deviations from ideal behaviour may also lead to frustration and competitive behaviour exacerbating the congestion. The role of managed evacuations has merit from the perspective of evacuating the most at risk floors first, thus mitigating local congestion and frustration that is perhaps attributable to a recognisable danger by those on the affected floors. Managed evacuations would avoid the development of conditions that would otherwise be responsible for slowed evacuation due to crowd crushing and increased risk to life.

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1. INTRODUCTION

In New Zealand the present NZBC Compliance Documents C/AS1 (DBH 2005) require that exit widths are determined primarily on the basis of the numbers of people that egress from each floor, but no mention is made for merging flows. So while it is assumed that egress routes satisfying C/AS1 provisions can accommodate the required people traffic, delays due to congestion at merging points during an emergency egress may exceed the evacuation time allowed for in the design.

As the subject of merging traffic flows is not specifically covered in C/AS1, the objective of this study is to evaluate what allowance if any is required for merging flows of people entering stairways from a floor exit.

More importantly if it is shown that merging congestion is only a minor issue and that there are other more complex factors (perhaps combinations of factors) that may on first glance appear to be a merging problem, then different ways to alleviate the original congestion problem may be considered.

1.1 Current New Zealand evacuation requirements

Excerpts from the current NZ Compliance Documents C/AS1 (DBH 2005) relating to evacuation requirements that apply to stairways where merging may occur are copied to Appendix B. These documents are also under review in 2010-11.

While the subject of merging pedestrian flows is not specifically covered there are requirements in the Acceptable Solutions which influence designs that by default limit the likelihood of congestion occurring, such as:

- establishing minimum widths of escape routes and exitways and then requiring exit widths based on occupant loads, but only on a per floor basis
- refuge areas in stairways of a minimum area are required every third floor for slow-moving people to rest and others to pass
- staged evacuation schemes where the floor of fire origin is the first to be evacuated
- requirements for a minimum number of escape routes with increasing occupant loads requiring a greater number of escape routes, on the assumption that one escape route may be inoperable due to the fire emergency
- fully openable doorways in escape routes may only reduce the width of the escape route by 125 mm
- a Voice Communication System required to coordinate staged evacuations
- pressurisation of vertical exitways with escape heights greater than 25 m and for at least 60 mins
- protected paths before any vertical safe path
- progressive increase in width for horizontal escape route
- where an escape route from upper floors is joined at a final exit by an escape route from a basement or lower floors, the escape route width at the point they

combine shall be increased to accommodate the occupant loads from both directions.

Otherwise in instances where fire engineering design is used, it is a requirement to show that the means of escape provisions achieve an equal (to the level specified in the NZBC) or better level of life safety.

Additional measures for ensuring stairways are relatively safe places that may be considered include:

- all the building occupants can fit inside the stairwells as a safe refuge
- the surface finish requirements inhibit fire spread
- the use of elevators to evacuate mobility impaired occupants.

Not all the provisions are necessarily required, but a well-reasoned selection based on a fire engineering solution is likely to result in evacuation solutions that meet life safety requirements for buildings on a case-by-case basis.

2. LITERATURE REVIEW

2.1 Dangers of choking flow

In extreme situations where panic occurs due to a very real and apparent danger, or just frustration with slow-moving pedestrian flow, a people crush may occur. If this kind of congestion occurs approaching an exit then the flow through the exit may reduce to a fraction of capacity, even though there are plenty of people available to move though the exit. In this situation it does not matter whether there are two merging flows or not.

An example of extreme congestion resulting in a choking crush occurred at the Rhode Island Station Nightclub in 2003 and was reported as follows (Grosshandler, Bryner, and Madrzykowski 2005).

> *The nightclub's fire alarm system had made everyone acutely aware of the impending danger, and, although there were four possible exits, most people naturally headed for the front door through which they had entered. The ensuing stampede led to a crush in the narrow hallway leading to that exit, quickly blocking the exit completely and resulting in numerous deaths and injuries among the patrons and staff. Of the 462 in attendance, 100 lost their lives, and about half were injured, either from burns, smoke inhalation, or trampling.*

Some other well-known instances of choking flow and/or crowd crushes are:

- 1985 Bradford stadium fire and crush, which claimed 55 lives (but crushes may occur without a fire)
- 1989 Hillsborough soccer stadium tragedy in England where 95 died in a crowd crush
- 2003 E2 nightclub stampede in Chicago, which claimed 21 lives in ensuing crowd crush in exit.

So it is not just merging flow scenarios that may result in congestion or, worse still, a crowd crush.

This study focuses on merging flows that may sometimes be responsible for congestion and choking flows, but a merging scenario may not have been the original cause. Many other factors may contribute to crowding problems.

2.2 NZBC treatment of merging flows in evacuations

The current New Zealand egress requirements in the Acceptable Solutions C/AS1 (DBH 2005) that may be relevant to the possibilities of congestion associated with merging were summarised in Section 1.1.

There is no specific mention of merging flows or means of mitigating the congestion that may result when flows merge, except where ascending stairs from a basement join stairs from the upper floors. In this instance the escape width increases to accommodate occupants from both directions.

Exit and egress path widths, above minimum requirements, are determined on the number of expected occupants, but only on a **per floor** basis and not on the occupancy of the whole building. So to satisfy the egress width, requirements of C/AS1 evacuation are only considered on a floor-by-floor basis with no formal requirements for increasing widths as flows from floors add together. For low-rise buildings of limited levels it is unlikely that merging flows will critically slow an evacuation. On the other hand multiple floors exits all entering the same stairway(s) is a scenario not addressed.

This study focuses on whether instances of merging are likely to cause increases in evacuation times that exceed that allowed for in a design.

Two considerations of merging:

1. Flow is slowed just because multiple streams merge (in a orderly fashion) into one, but the outflow is the same as the capacity of the stairway or the final exit and the building evacuates in the allocated time, or
2. The process of merging chokes the flow at that point, such that it may virtually come to a standstill or reduce the flow in a stairway both downstream and upstream of the merge point.

In the first case this is a completely normal and expected occurrence and unlikely to impact the "designed for" evacuation time very much. Hydraulic modelling of people flows is quite predictable.

The second case is potentially much more serious and unpredictable. The input variables become more dominated by human factors and emotions, such as fear and competition rather than deference. As a result the narrow band of expected outcomes suddenly becomes much wider.

2.2.1 ISO guidance on merging flows

The International Standards Organisation *Technical Report ISO/TR 16738* (ISO 2009) offers guidance on handling transitions in exit systems and the definition of a transition is wide. Where two flows merge into one is just one example as:

> *… the point where a corridor enters a stairway; there are actually two transitions: one occurs as the egress flow passes through the doorway, the other as the flow leaves the doorway and proceeds onto the stairs.*

The specific flow departing from transition point, *F*s(out), for cases involving two incoming flows and one outflow from a transition point (such as that which occurs with the merger of a flow down a stairwell and the entering flow at a floor) is calculated as given in ....Equation 1:

$$F_{S(out)} = \left\{ \left[F_{S(in-1)} W_{e(in-1)} \right] + \left[F_{S(in-2)} W_{e(in-2)} \right] \right\} / W_{e(out)} \quad \textbf{...........Equation 1}$$

Where: $F_{S(out)}$ is the specific flow departing from a transition point

$F_{S(in-1,2)}$ is the specific flow arriving at a transition point

$W_{e(in-1,2)}$ is the effective width before the transition point

$W_{e(out)}$ is the effective width after passing transition point

and the subscripts (iñ-1) and (iñ-2) indicate the values for the two incoming flows.

The calculation model presented here is described in more detail in the *SFPE Handbook* (3rd Edn) (Nelson and Mowrer 1995). It is based on the simple algebraic concept that the maximum flow rates into and out of a point where a route widens or narrows, or where two routes merge into one, are a function of the relative maximum specific flows and effective widths of the various elements. Thus when a route widens or narrows, the total flow rate, F_C, into and out of the "pinch" point is the same and the limiting factor is the maximum specific flow rate, $F_S$max, sustainable for the narrowest element.

Where two routes merge into one, it is assumed that the maximum calculated flow rate is also limited by the maximum specific flow rates and width of either the two inlets or the outlet, whichever is the limiting factor. The proportion of the flow from each inlet is assumed to be proportional to the ratio of the effective widths, *We*, of the two inlet elements.

Based on experimental and computer simulation modelling studies (Purser 2008), this assumption is considered to represent a somewhat simplistic model. At merge points between flows entering at storey exits with flows down stairs, it has been found that merge ratios tended to be 50:50, even when the stair and exit widths were somewhat different (but with comparable proportions). It is considered that the merge from the storey exit is facilitated by the fact that the stair flows turn through 180° at a landing, tending to take the shortest line and allowing occupants from the storey exit to enter the stairs.

These issues of potential flow dominance and deference behaviour are discussed in Clause 10 of ISO/TR 16738 (ISO 2009). In situations where merge rates are considered related to the effective width of converging elements (e.g. where the width of one entry is much greater than the other), the maximum flow rates may be estimated by the method described in this sub-clause.

The rules below apply to determining the densities and flow rates following the passage of a transition point:

a) The flow after a transition point is a function, within limits, of the flow(s) entering the transition point.
b) The calculated flow, F_C, following a transition point cannot exceed the maximum specific flow, F_{Smax}, for the route element involved multiplied by the effective width, *W*e, of that element.
c) Within the limits of rule b, the specific flow, F_S, of the route departing from a transition point can be determined for the following cases.

Further guidance on maximum flow rates through horizontal and vertical escape routes is presented by Nelson and Mowrer (1995) in the *SFPE Handbook* (3^{rd} Edn). The standing area on a stair depends on the building design. Little guidance is available about occupant densities on stairs, but the densities obtained in these experiments were found to be quite low (approximately two persons/m^2) under crowded conditions with slow flows (Purser 2008).

Merge ratio data are sparse and there are three main assumptions that are often used.

- the flow is dominated by occupants on the stairs and the building empties from the top floor down, or
- occupants on the stairs “defer” to occupants at storey exits and the building empties from the bottom up, or
- the merge ratio is around 50:50 at storey exits and the building empties from the bottom up.

Merging behaviour can have a considerable influence on the pattern of evacuation from a tall building. If the flow from the upper floor merges equally with the flow from the floor below, the flow rate from each floor is half the maximum flow rate from each storey exit in crowded situations. If the flow of occupants in a stairwell from the upper floor dominates, occupants from the lower floors cannot evacuate until those from the upper floor have gone.

This is the basis of the method used to calculate evacuation times for multi-storey buildings described by Nelson and Mowrer (1995). In other building configurations, various degrees of merging flows are likely to occur. In some cases, deference behaviour can occur, whereby occupants descending the stairs give preference to occupants entering the stairs and the storey exits. In such situations, the lower floors of the building clear first so that those on the upper floors can be delayed (Proulx 2002).

In computer simulations and experimental evacuations involving crowded conditions, merge ratios have been found to approximate to 50:50 for a variety of different buildings and stair layouts (Purser 2008).

2.2.2 Pre-movement time

Whiting (2005) extensively analyses pre-movement time from a New Zealand and international perspective reporting on high-profile fire incidents, studies, fire drills and their applicability to real fire evacuations. A common theme in cases where there is significant loss of life, and where congestion and crushing choking occurs, leaves no doubt that the incidents would have been much less tragic in terms of loss of life if people had begun evacuations sooner. In some cases viable exits were not used due to unfamiliarity of the building or the occupants just having a pre-disposition to leave by the exit through which they entered.

Looking ahead it is suggested that improvements and optimisation of the pre-movement times that are generally applicable to a range of occupancies are likely to be achieved where an appropriate mix of the following provisions is applied:

- a hierarchy of authority exists to install a thoroughly planned emergency response
- adequate training is provided to those appointed to take control (fire wardens)
- all occupants are familiar with the whole plan, not just their part in it, and the familiarity is reinforced through regular trials
- effective and accurate information is readily able to be communicated to those who require it, when they require it.

Caution should be exercised using pre-movement data that has been collected from trial evacuations as these represent idealised situations. Such trials test that systems work and occupants know the procedure, but in reality occupants may be faced with ambiguous cues in major fire incidents that may result in actions that do not follow theoretical behaviour.

The occupancy type may also be a factor in responses to fire emergencies, with the association between occupants also being a factor. The higher degree of association between occupants, the greater the level of collective action, such as family members at a very high level and below that employees in a workplace who will to an extent look after each other but essentially only have themselves to consider. In a working purpose group occupancy, where a building has a reliable means of raising the alarm, effective fire wardens and regular practices, then the pre-movement component is likely to be predictable within a small range.

In sleeping and crowd occupancies the prediction of the pre-movement component is considerably more difficult where greater affiliation between occupants is likely to over-ride external instruction. Another factor, prevalent in crowd situations and to a lesser extent in working occupancies, is the negative influence of peer group pressure preventing any response action for fear of standing out or being seen to over-react. This is a cultural phenomenon common to New Zealanders not wanting to be seen as a “tall poppy” or “non conformist”. Furthermore the range of response times is likely to be covered by a wide distribution at night as people wake at different times in response to an emergency alarm or other indication (ISO 2009). As a result the flow capacity of the exitways is unlikely to be exceeded by a sufficient margin for there to be any congestion attributable to merging flows at the entrance to stairways.

A favourable outcome would be some assurance that all occupants of all buildings are familiar with an evacuation plan, to respond promptly and to have practised that response, and then there would be no question as to a suitable estimate of the pre-movement component. But there are many situations where this will never be able to be relied upon.

Further guidance on actual numbers to use for pre-movement or delay times is given in ISO/TR 16738 (ISO 2009). In the context of this study no further analysis of pre-movement time will be included as its influence on possible merging has been covered above.

2.2.3 Flow time

Hydraulic models generally deal only with flow characteristics in a fluid mechanics sense without consideration of any human traits, such as the decision-making processes taking on a myriad of inputs making behavioural predictions more difficult.

With hydraulic flow calculations merging streams can be modelled by assigning a merge ratio, perhaps according to research findings and the procedures proposed in Section 2.2.1.

For instance models calculate flow door to stair and in stairs as if only evacuating that floor matters. This would be true if all of that flow could fit into the stairway before flow from the floor above catches up and a merge problem forms. That may slow the effective flow in each merge to half speed and so on up a building halving (in the case of a 50:50 merge) the flow each time to ¼ to $^1/_8$ to $^1/_{16}$ and so on upwards.

Hydraulically speaking only, the issue of evacuation time comes down to the influence of just one restrictive point (or flow exit) that will control the flow of an exit path. From that perspective what happens upstream in terms of merging hardly has any influence on the total evacuation time.

On this basis, from a purely hydraulic perspective, the only significant degree to which merging affects the evacuation is the order in which floors are cleared.

2.2.4 Merging

Experimental studies of merging onto stairs in five buildings by Purser and Boyce (2009) and Boyce, Purser and Shields (2009) conclude the following:

- 50:50 merge ratio average
- ratio of merge may oscillate over range 70:30 in favour of stairs or floor
- 86.7 persons/min/m flow rate for corridors
- 60.1 persons/min/m flow rate for stairs
- density of 2.08 persons/m^2 on stairs.

Table 1 records the individual merge ratios, averages and maximum variations for each building.

Table 1: Merge ratios between stair and storey exits on landings

	Merge ratio average stair:floor	Merge ratio variation maximum to stair	Merge ratio variation maximum to floor
Jordanstown Level 3C	51:49	69:31	30:73
Jordanstown Level 4B	46:54	52:48	36:64
Magee 1st floor	52:48	66:33	46:54
Canary Wharf	50:50	57:43	51:49
Central London Office	54:46		
Overall average ratio	50.6:49.4		

Other observations in the above study and other studies involving evacuation modelling (Galea, Sharp and Lawrence 2008b), indicate that there are some variations with opposite and adjacent flows:

- adjacent flows favour the floor flow entering the stairwell and a bottom up evacuation scenario
- opposite flows favour the flow already on the stairwell tending more to top down clearance.

There is also some suggestion by Galea, Sharp and Lawrence (2008b) that opposite flow merging should be encouraged to favour upper floors clearing sooner. This is on the basis that the frustration due to a lack of egress movement experienced by people on the upper floors may be marginally alleviated.

Choking flow at merge points (as a result of crowd crush) was not really a factor except in extreme circumstances. This indicates a difference between what happens in observed evacuation drills for experimental purposes compared with post-emergency interviews in real evacuations. The latter encapsulates the type of data that ultimately tests the evacuation characteristics, giving a true representation rather than artificial data that is albeit of greater depth.

The findings of some post-evacuation interviews are included in Section 2.4.

2.3 Evacuation schemes

A benefit of evacuation schemes is that they also contribute to a reduction in pre-movement time or delays in initiating evacuations, and can be crucial in whether occupants get out in time. Time wasted in deciding whether to leave or when to start leaving may mean insufficient time for a safe evacuation. Also, managed evacuation schemes by default may include the facility to evacuate the most at risk first fire floor.

2.3.1 New Zealand requirements for evacuation schemes

Evacuation schemes are required under the Fire Service Act 1975 No 42, 21B(2). The New Zealand Fire Service (NZFS 2010) requirements for evacuation schemes (that are approved by NZFS) are fully covered in Appendix C.

By way of a brief summary the primary consideration is that buildings with more than 100 people, which by default means any building where congestion may occur, is required to have an approved evacuation scheme. Other requirements are for evacuation schemes for buildings of much less than 100 occupants, but for other fire safety reasons they are not relevant in this study because congestion as a result of merging flow is not considered to be a problem.

Signage of the type specified in the example in Appendix C is required detailing the procedure for occupants in the event of fire.

Principal features of the instructions that may be followed in the event of fire are:

- warn other building occupants
- operate the fire alarm
- phone fire service (dial 111)
- leave the building immediately using the nearest exit (that exit is specified)
- specify alternative exits
- mark assembly points
- walk, don't run
- stay at assembly point until "ALL CLEAR" is given
- do not attempt to extinguish fire unless it is safe to do so.

On the BRANZ site, instructions for the employee fire-fighting team say to only attempt to control a fire with hydrant fire hoses from outside the buildings. There is no mandate permitting fire-fighting from inside the buildings.

The advice to leave the building immediately in the event of a fire alarm will, if nothing else, theoretically keep the pre-movement time to a minimum.

Whatever signage pertaining to an evacuation scheme is used, NZFS approval is required.

Staying at the assembly point implies that it is not permitted to return to one's workplace or re-enter the building.

Listing alternative exits may not help much in the immediate instance of a fire alarm if occupants are unfamiliar with a building and seek out the exit through which they entered. But clear marking of all fire exits at least makes alternative exits visible.

It does not appear that NZFS evacuation schemes are intended to give advice on or require staged evacuations.

The NZBC Compliance Documents C/AS1 (DBH 2005) cover the necessary provisions for the implementation of staged evacuations by Type 8 alarm requiring a Voice Communication System as covered in Appendix B of this report.

Briefly a Voice Communication System is intended to fulfil the following function:

> **Fire Safety Precautions**
>
> **Type 8: Voice Communication System**
>
> An automatic system with variable tone alerting devices, the facility to deliver voice messages to occupants, and to allow two-way communication between emergency services personnel.
>
> Voice Communication Systems shall comply with AS 2220: Parts 1 and 2 (SA 1989a & 1989b).
>
> **COMMENT:**

> A Voice Communication System, particularly in tall *buildings*, permits controlled evacuation. In cases where the sprinkler system and Fire Service achieve early control of the *fire*, it may be necessary to evacuate only part of the *building*.

At present C/AS1 (Table 4.1) only requires a Type 8 Voice Communication System in buildings with the sleeping purpose groups SC (sleeping care), SD (sleeping detention) or SA (sleeping accommodation), but not SR (sleeping residential), with an escape height greater than 25 m.

The crowd activities with large congregations (purpose group CL) of people (such as shopping centres, entertainment venues and working activities with offices in tall buildings) are generally outside this requirement except in some circumstances such as where a protected path does not precede a vertical path. This does not mean, however, that a Fire Design outside the Acceptable Solutions may not deem a Type 8 Voice Communication System to be required, nor that this system is included anyway as required for everyday operations.

2.4 Evacuations in real emergencies versus drills

For multi-storey evacuations (Purser and Gwynne 2007) the main findings were that for design maximum populations and a typical stair layout (two flights with a mid-landing and storey exit landing), the time to clear each floor into the stairs for any particular exit and stair width is very dependent on three parameters:

- the assumed maximum flow rates through storey exits, on stairs and through final exits
- the "standing" capacity of the stair between floors – which for a given stair depends upon the assumed "packing" density taken up by the occupants as they descend the stair
- the merge ratio at the storey exits between occupants on the stair and those from the floor.

Nowhere is there any data on congestion (choking) as a result of merging which would be the result of pushing and shoving by people being scared as a result of being under threat from real (and potentially) life-threatening indicators, such as smoke and fire as opposed to a relaxed and orderly drill. So the real situation that becomes life-threatening could be completely different even if panic is very unlikely as covered in Section 2.5 below.

2.5 Concerns raised by WTC evacuations

For buildings (Bohannon 2005) at the upper bounds of height, such as skyscrapers, the egress provisions are not designed to disgorge all their occupants in a dire emergency. Instead evacuation provisions are designed on the premise that the prime intention is to evacuate the affected floors into the stairwells only, the 9/11 terrorist attacks on the WTC towers being an example. The 1993 terrorist bomb in the basement also revealed that several hours were required to evacuate a building of that size.

The studies (Averill et al 2005; Galea et al 2008a; McConnell 2010), including survivor interviews and evacuation modelling, further concluded that had the buildings been fully occupied with 20,000 people in each tower (40,000 total instead of the approximately 17,400 estimated to be present (NIST), the stairways (below the impact floors) would have become gridlocked very early in the evacuation resulting in some 14,000 deaths.

Tall buildings are not designed to be fully evacuated; regulations typically require that only a few fire-affected floors be emptied on the assumption that a fire is contained and localised.

In interviews of 3,000 survivors in two separate studies (USA and UK references as above) a most surprising discovery was the long time lag between the first attack (aircraft impact) and the start of the evacuation. Within 5.0 mins 77% of survivors began egress and it took another hour for the next 19% to start moving and 4% stayed in their offices for over an hour. In some cases people were more worried about saving their computers.

2.5.1 Pre-movement activities

Incorporating the pre-movement time into evacuation models show that with full occupancy it was estimated that roughly 14,000 deaths would have resulted with most of them stuck on the stairs, presumably when the buildings collapsed. In any case the stairs were not designed to handle a full evacuation, as is the case for many tall buildings. NIST is promoting provisions for full building evacuations in the next review of the USA building codes. Collier (2008) reports that for the minimum width of stairways (in the USA) it has since been proposed that it be increased from 44 to 56 in (1,120 to 1,420 mm), but more to account for an increased size of people.

Resistance to changes that require full building evacuation are based on the supposition that the WTC attacks were a one-time-only event. However realities show that for buildings with a typical lifetime of 100 years designers should be preparing for other extreme events like multi-floor fires, earthquakes and hurricanes (not to mention the continuing threat of terrorist bombs worldwide).

2.5.2 Realities of emergency evacuations

For all of the evacuation provisions included it is essential to understand that an emergency changes everything. Strange things happen when fear is added to the mix. Consider the paradox that the more urgently people want to leave a crowded room with a narrow exit the longer it takes to get out.

Studies by Berrou and Kerridge (Bohannon 2005) show that in uncramped non-emergency situations people in crowds navigate and negotiate priority in crowded spaces with cues transmitted through body language, in other words a non-verbal communication scenario. Understanding how that works may assist in quantifying why certain geometries of corridors and portals (entrances, exits etc) operate better than others. It is also acknowledged that cultural variations in crowd behaviour exist, probably governed mainly by population densities and people’s perception of personal space.

Introduce an emergency situation and the above rules are likely to change, the hitherto normal communication breaks down and a herd mentality takes over. Studies by Kerridge (Bohannon 2005) reveal that the fundamental unit of a crowd is no longer the individual but a cluster. The first thing people do in an emergency situation is look to each other for support and information and this response slows movement dramatically.

On a larger scale people form groups similar to animal herds in which individuals let the crowd do the navigating, often passing right by exits within clear view. Learning to predict and control these behaviours may save lives – and not just in large buildings. The main killer when people mass is not trampling, as is commonly thought, but "crowd crush". When two large groups merge or file into a dead end, the density makes it impossible to fall down (Pauls as cited in Bohannon 2005). But the accumulated pushing creates forces that can bend steel barriers.

> *"The situation is horrible". "Suddenly everything goes quiet as people's lungs are compressed. No one realises what is happening as people die silently. Dangers like these make designing architecture and procedures for evacuation like a tightrope walk. You have to get people out fast, but safely".*

It is further noted in the WTC evacuations (Cmmdocs 2005) that the exit flow reduced in the final ~20 mins of the evacuation (before the collapse of WTC 1) indicating that stairways were being utilised below capacity. Either the bulk of occupants had escaped and the stairs were flowing freely towards a supposedly slightly restrictive exit, or of more concern (unverified) there was a choke point (bottleneck) upstream that was impeding the flow.

2.5.3 Fitness and mobility

An important observation by Galea et al (2008a) in the post-WTC studies is that Body Mass Index (BMI) does not appear to be a predictor of the need to rest or of stair travel speed. This is more a consequence of the congestion slowing travel speeds to a pulsating or stop/start nature whereby occupants are often forced to take a rest stop before they may actually need one. Consequently a lack of mobility or fitness is not a predominant factor in a congested evacuation, except for the severely mobility impaired who may require assistance.

This finding counters the findings of a BRANZ study looking at the need to increase widths of egress routes (Collier 2008) to cater for the increased size (BMI) of today's population. However to put it in perspective there is a difference between a relatively free-moving egress and a choked, pulsating, and sometimes completely stopped flow. There is also another obvious factor that bigger people (greater BMI) will take up more space, whether moving or stationary, so the specific flow must also reduce.

2.5.4 Recommendations

Given that existing buildings are likely to still have considerable serviceable life remaining, improvements will have to be by better emergency procedures and retrofitting. The use of elevators should be considered during emergencies (Sunder quoted in Bohannon 2005). WTC 2 emptied far more efficiently than WTC 1 because its elevators were serviceable before it was hit by the second plane. New elevator systems that include independent power supplies and computers that prevent them from opening on a burning floor will be available in a few years (Averill 2005). The suggestion of providing sky bridges (Galea quoted in Bohannon 2005) between buildings is an innovative idea – simulations suggest far more efficient WTC evacuations.

In reality the best thing that can be done to make buildings safer (Pauls quoted in Bohannon 2005) is to focus on the basics such as better stairs, elevators and fire drills that emphasise leaving the building immediately, thus reducing pre-movement time.

3. EGRESS MODELLING

In a general article on integrating human behaviour factors in fire, O'Connor (2005) considers computer-based models and these can be categorised as either:

1) hydraulic or network models
2) behavioural models.

The characteristics and differences between the models are identified in Table 2.

Table 2: Hydraulic versus behavioural models

	Hydraulic models	Behavioural models
Distance, speed, density and flow considered	Yes	Yes
Occupant characteristics/ behaviours/decisions integrated	No	Yes
Occupant responds to fire or environment	No	Yes

In both the hydraulic and behavioural model, movement of people is always a function of distance, speed, density and flow – as would be the case in homogenous flow. When using hydraulic models, it should be recognised that flows are basic assumptions that may require further consideration via integration of safety factors or alternation of parameters to provide conservatism. For example a hydraulic model assumes:

- all occupants start egress at the same time
- occupant population will divide to the exits in an optimum balance
- occupants will know building evacuation routes
- occupants will select the shortest egress path.

While these are optimistic assumptions, more realistic assumptions can be tested. Once the parameters and methodology of a hydraulic model are understood, it is possible to modify the input parameters and perform a further analysis to bias the results towards more pessimistic assumptions such as a blocked exit, travel speed reduction and occupants using a longer exit path.

With the advent of behavioural models, the movement of people as fluid particles is modifiable by numerous other parameters that attempt to integrate behaviour related to the population characteristics, building characteristics, individual decision-making capacities and the fire environment. A significant number of evacuation models have been developed, and a concern for the variability and uncertainty of the behavioural models has been ignored (Meachan 2004). Continued focus on these models will likely provoke improvements so they may eventually become common and useful tools for building design.

3.1 Hydraulic models

Hydraulic models do not take into account human factors – they are simply based on the fluid flow parameters mentioned above.

An example of an evacuation of a nine floor office building involving merging (of which eight floors are occupied) with 300 occupants per floor is modelled by Gwynne and Rosenbaum (2008). There are two stairways serving the building so it is assumed 150 persons from each floor would use each stairway. The clearance time is totally dependent and controlled by the flow through the stairway exit doors. An approximate estimate of the evacuation time is determined by the time for the entire occupancy to flow through that exit.

The worked example demonstrates the application of 1st and 2nd order hydraulic models to solve the evacuation problem:

- In the case of the **1st order solution** the final exit from the stairway is identified as the choke point in the flow, a 0.9 m wide door that has a flow of 48 persons per min. Half of the occupancy (of 2,400), i.e. 1,200 people, is required to pass through the final exit and this would take approximately 25 mins (or 1,500 secs). Additional to the flow time through the exit is the time taken for the first person to reach that exit and this is the time taken for first occupant on the lowest floor to travel down one flight of stairs (in this case 0.4 mins) and emerge through the final exit. The total evacuation time is therefore 25.4 mins (or 1,524 secs), but does not include any allowance for the first person on that floor to reach the stairs. This example is a relatively simple evacuation problem and a more complex example may make it difficult to determine which restriction is the choke point.
- In the **2nd order solution** the whole network is considered including merging of the pedestrian flows at each floor entrance to the stairways. For the purposes of this example it is assumed that the merging favours those already on the stairs (100%), and those on the floors must wait until the entire flow on the stairs from the floors above has cleared before they may enter the stairs. This is known as a **top down** evacuation. This more complex calculation produced an evacuation time of 25.3 mins (1,518 secs), only marginally less than the 1st order solution.

To further examine this simple evacuation the principles of the 2nd order solution have been entered in a spreadsheet with some Visual Basic code to perform the calculations involving the looping. This has permitted the merge ratio to be varied from 0:1 to 0.5:0.5(50:50) to 1:0. It was even completely randomised to demonstrate that the merge ratio does not alter the total evacuation time, only the rate at which floors empty. Some examples are presented in Figure 1 to Figure 6. The initial movement time of the first occupants to the stairs and stair filling time is not included for simplicity, as only the relative comparison between merge ratios is considered.

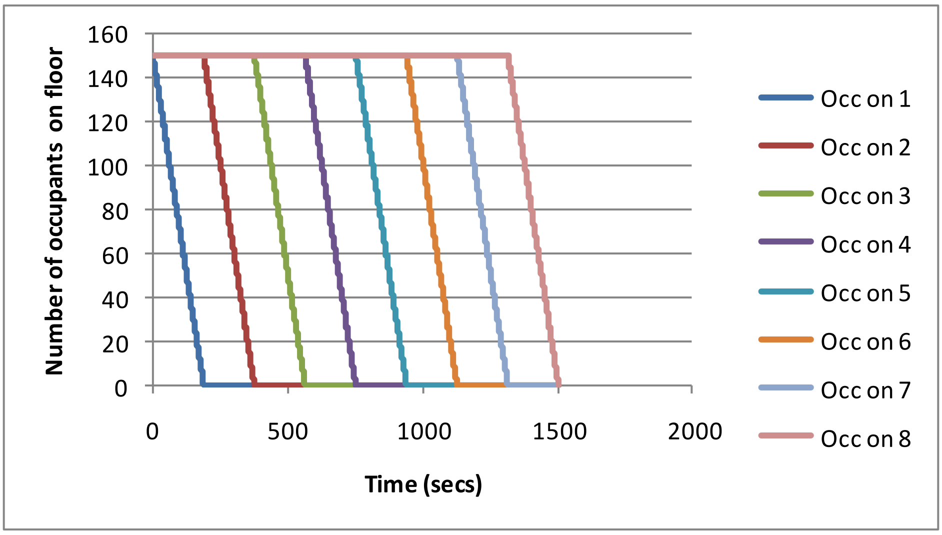

Figure 1: Evacuation with merge ratio 1:0 in favour of floor first, bottom up evacuation

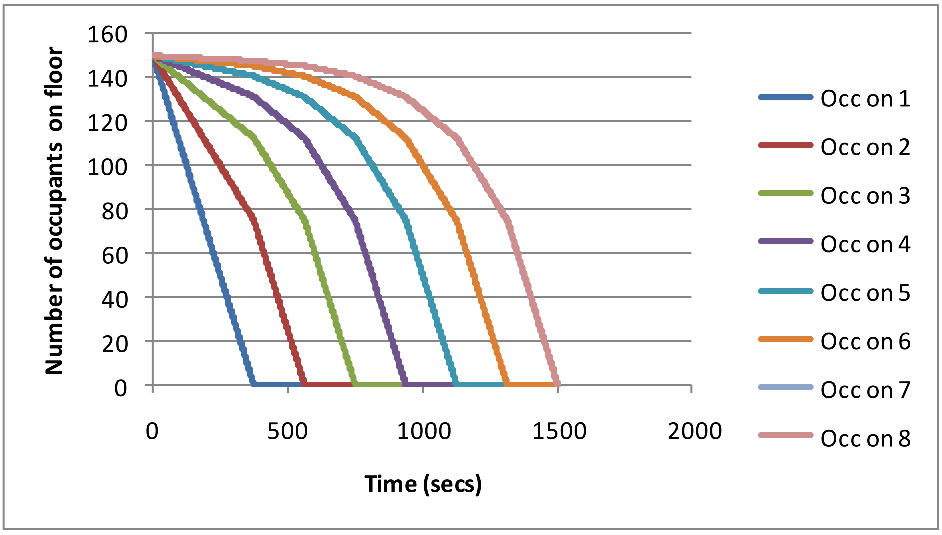

Figure 2: Evacuation with merge ratio 0.5:0.5 results in a bottom up evacuation

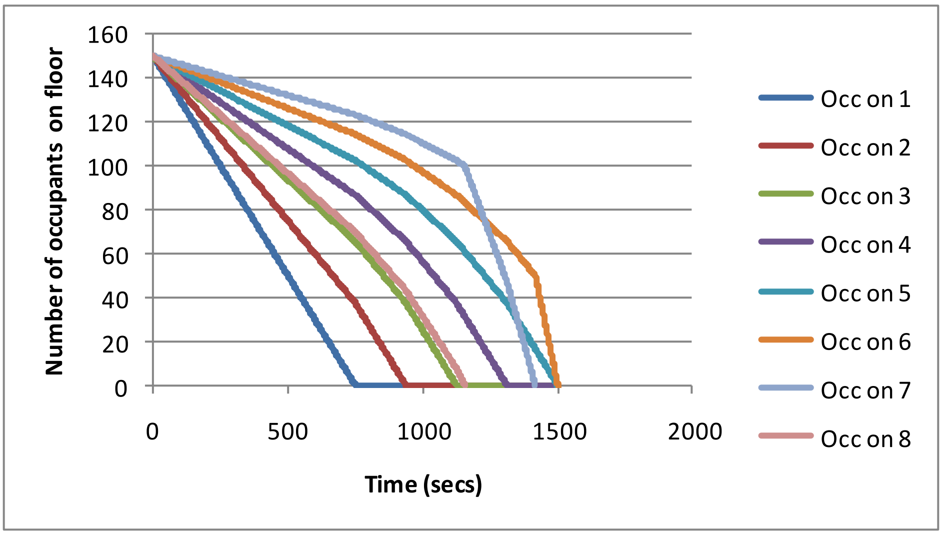

Figure 3: Evacuation with merge ratio 0.25:0.75

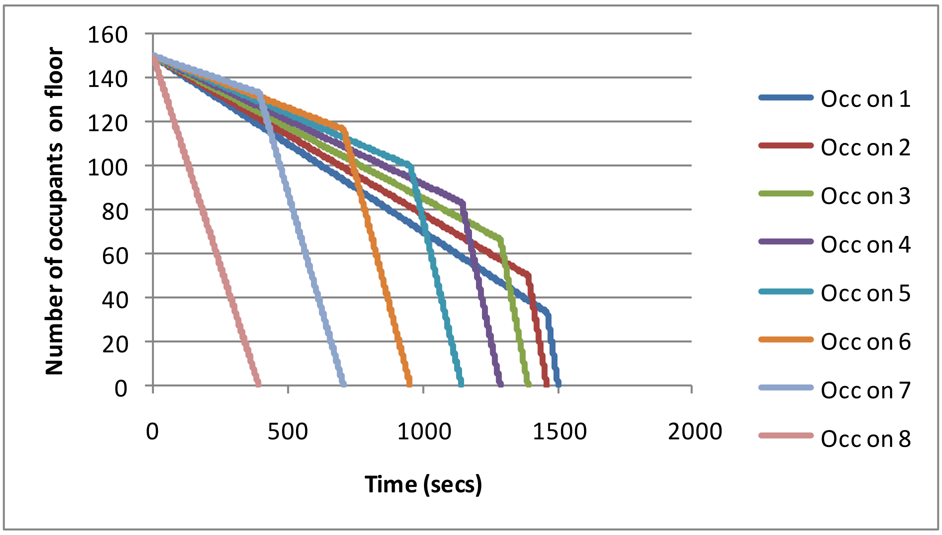

Figure 4: Evacuation with merge ratio 0.1:0.9 top down evacuation

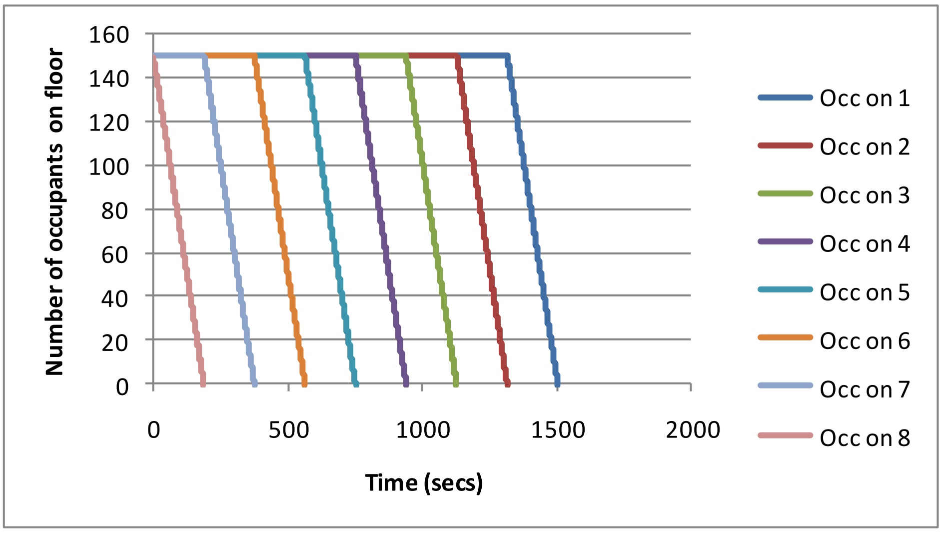

Figure 5: Evacuation with merge ratio 0:1 in favour of stairs, top down evacuation

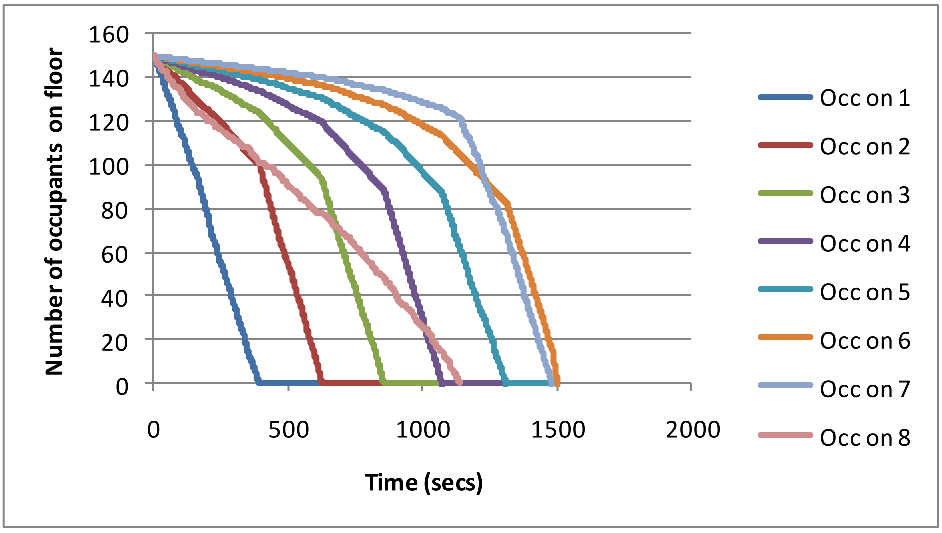

Figure 6: Evacuation with a random merge ratio generally a bottom up evacuation

A summary of the modelled evacuation times in Table 3 shows them to be totally independent of the merge ratio.

Table 3: Merge ratio versus evacuation time

Merge ratio stair:floor	Evacuation time (secs)	Evacuation direction top or bottom first?
1:0	1506	bottom
0.75:0.25	1506	bottom
0.5:0.5	1505	bottom
0.25:0.75	1504	bottom
0.1:0.9	1504	top
0:1	1505	top
random	1505	bottom

It would appear that there is a break point in the merge ratio between 0.1 and 0.25 where the clearance direction changes from a bottom up evacuation to top down. Any extreme bias of merge ratio of 0.25 or less was not supported by observations in trial evacuations. On that basis it is extremely unlikely that a top down evacuation will occur without intervention, such as a staged evacuation.

Finally as explained above for hydraulic models (of which this is a simple example) no account of human factors is included. If human factors such as pushing and shoving in order to evacuate were included it is also unlikely that the overall evacuation time would be affected very much. What is more likely is that the downstream gap in the stairs left by any choking would be filled by an increased flow from other entry points to increase the pedestrian flow up to capacity. The concern that needs consideration is that the very point where congestion occurs may be where the danger is greatest, such as a fire-affected floor from which it is vital that the occupants be evacuated from first.

To an observer/evacuee on an upper floor it may at times appear that the flow is completely choked, but in fact it is the merging on the lower floors that is progressively holding up the flow on the upper floors. Frustration (at it taking up to 25 mins to evacuate) could then be a factor for people on the upper floors that may lead to more aggressive behaviour resulting in choking and crushing and a serious problem.

3.1.1 Gridflow

Gridflow is a well-developed hydraulic model written by Bensilum and Purser (2002) and the default is a 50:50 merge ratio. The model incorporates all contemporary and validated data of flow rates for horizontal and vertical travel, maximum people densities and delivers usable data for evacuation analysis.

It is possible to enter complex building designs with varying features in order to determine an evacuation time. However in simplistic terms evacuation occurs from the bottom up, as expected for the 50:50 merge ratio.

Attempts to include real-life variations of human behaviour have been introduced in the form of a log normal distribution of the pre-movement time. This is biased towards a response to the initial alarm, with some people deciding to move immediately followed by the mean. However, there is a long tail indicating some people may remain for much longer before deciding to leave the building.

3.2 Modelling a tall building in New Zealand

In the context of this study on merging and resulting congestion two simple examples are given for New Zealand buildings to demonstrate evacuations scenarios likely to be expected.

1. **Rutherford House, 1 Lambton Quay, Wellington**

The evacuation of Rutherford House is taken from the recollections of the author during the 1970s and 1980s when the building was the Head Office of the New Zealand Electricity Department. As an occupant the author experienced many complete evacuations of the building during fire drills.

The building parameters were:

- 13 occupied levels above ground level (12 floors + mezzanine)
- approximately 500 occupants distributed between the 13 levels, but not uniformly
- two stairwells running the entire building height servicing each floor
- stair widths 1,200 mm, handrails on each side
- doorways 900 mm wide to stairwells opening outwards from stairs
- merging flow floor to stair in an adjacent direction
- egress instruction for odd and even numbered floors to use opposite stairwells
- four elevators in central well, but not to be used during evacuations

Estimated evacuation times:

With two stairwells available:

Pauls (1980) and (ISO 2009) high-rise evacuation time
$T= 0.68 + 0.081p^{0.73} = 5.60$ mins

Where p = 500 persons / ((1.2-0.3) x 2 stairwells) = 278 persons/m of stair width

Or if only one stairwell was available:

Pauls' high-rise evacuation time
$T= 0.68 + 0.081p^{0.73} = 8.85$ mins

Where p= 500 persons / ((1.2-0.3) x 1 stairwell) = 556 persons/m of stair width

The stair-holding capacity per storey including landings can be determined on the basis of the standing area according to:

$Y = 15.6 \times width^{1.66}$

Where, the width is in meters (m) and the area (Y) in m^2.

This formulation is based on a regression of the simultaneous evacuation requirements and a recommended standing space for 2 persons/m^2 in a stairway (Purser 2011), and as in Approved Document B (AD B 2000) for determining stair designs:

$Y = 15.6 \times 1.2^{1.66} = 21\ m^2$ persons in each 1,200 mm wide stairwell per storey.

Or for entire building:

2 stairwells x 21 m^2 x 13 floors = 546 m^2.

If the entire building occupancy of 500 were to occupy the stairwells then the density would be:

500/546 = 0.9 persons/m^2.

Even with only one stairwell available the density would be:

500/(546/2) =1.8 persons/m^2.

On the basis that 2-4 people/m^2 is an acceptable density (Purser 2008, Purser and Boyce (2009) and Boyce, Purser and Shields 2009) of people in escape routes the stairwells offer an acceptable refuge. So the entire building occupancy would comfortably fit in the protected stairwells. However, the stairwells were not pressurised so an ongoing evacuation would be required.

The egress instruction was later changed to use the stairwell nearest your location at alarm time. This was because there never appeared any need to stagger entry to stairwell to prevent congestion and the change of instruction did not appear to result in any perceivable difference.

Author observations:

- actual evacuation time in drills was about 6.0 mins, and this perhaps accounts for some pre-movement time
- no significant delay was ever experience in drills when exiting from the 4th level, and egress proceeded smoothly without impediment.

Concluding comment: The emergency egress provisions and plan for Rutherford House worked very well. This is also attributable to clear building warden instructions to all occupants and regular drills.

Table 4: Summary of Rutherford House evacuation

	Two stairwells (estimate)	One stairwell (estimate)	Actual drill (2 stairwells)
Evacuation time, mins	5.6	8.8	6

2. Vero Centre, Auckland (New Zealand's tallest building) see Appendix D

The actual and assumed building parameters are:

- height 167.5 m
- 38 floors
- floor area 68,900 m^2, 39,450 m^2 of lettable space
- five levels of podium space
- 32 levels of office space
- assume 1,000 m^2 per floor for offices
- on the basis of 0.1 persons/m^2 C/AS1 Table 2.2 (DBH 2005) and in Appendix B of this report
- 100 persons per office floor
- approximately 3,200 occupants distributed on the 32 levels of office space, but not necessarily uniformly
- 12 elevators service the building.

The design of escape routes as required by DBH (2005) Table 3.1 specifies their number based on the number of occupants on each floor. So for a floor of 100 occupants two escape routes are required.

Similarly the combined total width of all escape routes is based on the number of persons served. In the case of vertical travel for 'working groups' the combined width of all escape routes the requirement is 9 mm per person for vertical travel.

Therefore the required width:
9 mm x 100 = 900 mm.

But the minimum width for each individual escape route is:
1,000 mm.

So two stairways of 1,000 mm width are required, and these are to service all 32 office floors.

For doorways the fully open width may only reduce an escape route width by 125 mm. So the minimum door width servicing the stairways is 875 mm.

Estimated evacuation times:

With two stairwells available:

Pauls' high-rise $T = 0.68 + 0.081p^{0.73} = 23.6$ mins

Where p = 3,200 persons / ((1.0-0.3) x 2 stairwells) = 2,285 persons/m of stair width less 0.15 m each side to allow for boundary layer.

Or if only one stairwell were available:

Pauls' high-rise $T = 0.68 + 0.081p^{0.73} = 38.7$ mins

Where *p*= 3,200 persons / ((1.0-0.3) x 1 stairwell) = 4,571 persons/m of stair width

The stair-holding capacity per storey including landings can be determined on the basis of the standing area according to:

$$Y = 15.6 \times \text{width}^{1.66}$$

Where, the width is in meters (m) and the area (Y) in m^2. This formulation is based on a regression of the simultaneous evacuation requirements and a recommended standing space for 2 persons/m^2 in a stairway (Purser 2011), and as in Approved Document B (AD B 2000) for determining stair designs:

$Y = 15.6 \times 1.0^{1.66} = 15.6\ m^2$ persons in each 1,000 mm wide stairwell per storey.

Or for entire building = 2 stairwells x 15.6 x 32 floors = 998 m^2. If the assumed entire building occupancy of 3,200 were to occupy the stairwells then the density would be 3.2 persons/m^2. If a density of 4 persons/m^2 is considered a maximum, then if only one stair well were available it would not be possible to accommodate the entire building occupancy and there is a case for a staged evacuations.

Table 5: Summary of Vero Centre evacuation

	Two stairwells (estimate)	One stairwell (estimate)	Actual drill (2 stairwells)
Evacuation time, mins	23.6	38.7	NA

However, this assumes occupancy of 100 persons per floor, which may be significantly higher than actually the case. It is also a reasonable assumption that the office part of the building may only be 70% occupied at any one time due to absences or people just “out of office” on business. In this case the egress times may reduce to 18.4 or 30 mins respectively (a reduction of 5-8 mins) for two or one stairways being available.

3.2.1 Merging

From the previous example in Section 3.1 it was shown that with merging, no matter how the ratio deviates, the overall egress time is not significantly affected. What is important is how long people will be in immediate danger as a consequence of being delayed in exiting their floor if the stairs below them are moving slowly. The higher up the building the slower will be the people movement towards and on the stairs.

For the two examples Rutherford House does not present much of a problem in delays of any kind including merging. The Vero Centre, because of its much greater height, will create significant delays on the upper floors if it is attempted to evacuate all floors at once. Managed/staged evacuations would be the preferred option. Pressurisation of the stairs is currently required for buildings of that height, but not a Voice Communication System, so staged evacuations will not be easily implemented.

3.3 Modelling attempts to include human factors in the merging process

Galea, Sharp and Lawrence (2008b) have examined various means of including deference behaviour and architectural features into modeling multi-floor building evacuations. The representation of the merging process at the stair:floor interface is examined within a comprehensive evacuation model and trends found in experimental data are compared with model predictions. The analysis suggests that the representation of stair:floor merging within the comprehensive model appears to be consistent with trends observed within several published experiments of the merging process. In particular:

- the floor flow rate onto the stairs decreases as the stair population density increases
- for a given stair population density, the floor population's flow rate onto the stairs can be maximised by connecting the floor to the landing adjacent to the incoming stair
- in situations where the floor is connected adjacent to the incoming stair, the merging process appears to be biased in favour of the floor population.

It is further conjectured that when the floor is connected opposite the incoming stair, the merging process between the stair and floor streams is almost in balance for high stair population densities, with a slight bias in favour of the floor stream at low population densities.

A key practical finding of this analysis is that the speed at which a floor can be emptied onto a stair can be enhanced simply by connecting the floor to the landing at a location adjacent to the incoming stair rather than opposite the stair. Configuring the stair in this way, while reducing the floor emptying time, results in a corresponding decrease in the descent flow rate of those already on the stairs. While this is expected to have a negligible impact on the overall time to evacuate the building, the evacuation time for those higher up in the building is extended, while those on the lower flows is reduced. It is thus suggested that in high-rise buildings, floors should be connected to the landing on the opposite side to the incoming stair. Information of this type will allow engineers to better design stair:floor interfaces to meet specific design objectives.

There are two sets of conclusions from this work:

- one referring to the manner in which the building EXODUS (Galea et al 2000) evacuation software represents merging behaviour, and
- another relating to the nature of the observed general trends of the merging behaviour.

Based on the limited detailed data currently available from physical experiments and evacuation drills, the building EXODUS software appears to be able to reasonably represent the physical and some of the social factors that influence the stair:floor merging process observed in these situations.

However, as the current detailed knowledge base is limited to contrived experiments and evacuation drills, it is not clear if the observed behaviours are sufficient to describe the merging process in real emergency situations. Two studies on the evacuation of the WTC on 11 September 2011 (discussed in Section 2.5) gives valuable insights into occupant behaviour in real emergencies. Emergency conditions change everything especially when fear is added to the mix. Individual behaviour gives way to a herd mentality whereby the crowd takes over and the individual's ability to make decisions is diminished. In the context of merging flows the likely outcome of just one of the streams being subject to a herd mentality is the potential choking of both streams of the merge process if the crowd crush is bad enough.

Being able to predict the probability of occurrence of congestion and subsequent outcomes by modeling human behaviour on the basis of physical and social processes is at best challenging. However, it is more likely difficult and unreliable where a probabilistic range of outcomes is the output. Design decisions based on a lower bound (pessimistic) outcome is a practicable pathway to enable appropriate prevention measures to be advanced.

The study concludes that the merge ratio has a negligible impact on the overall time to evacuate a building. It is even suggested that floors should be connected to the landing on the opposite side to the incoming stair to balance the flow for high average stair occupancies. However, the bottom line is that current detailed knowledge is generally limited to contrived experiments and evacuation drills and it is not clear or certain that observed behaviours are sufficient to describe the merging process in real emergency situations. Furthermore, the modelling of credible human behaviour in such real situations remains an intractable challenge as there is just so much potential variation. Either the most pessimistic of outcomes needs to be considered, or alternatively active intervention in the process (such as staged or managed evacuations) can be examined as at least this offers the prospect of predictable outcomes.

4. DISCUSSION AND CONCLUSIONS

On the basis of various studies the merging of pedestrian flows entering stairwells has been shown not to introduce an undue impediment to egress flows.

This study concludes that merging is unlikely to be the sole cause of congestion even if it appears that congestion most often occurs at the point of merging. Various combinations of other factors were observed to be present. Effective solutions are both design and operational, and offer practical means of reducing congestion and ensuring that evacuations proceed within the performance parameters intended.

Trial evacuations confirm:

- that congestion at the point of merging of stair and floor flows has only minimal influence on overall building evacuation time
- the egress time is usually dependent on the flow at a critical point, for instance the doorway at the final exit point or another single restrictive point that governs the flow
- rarely (if at all) was it shown that congestion at merging points was responsible for critically choking the flow
- deference behaviour (or politeness albeit in non-panic situations) is the main contributor to a near 50:50 merge ratio, and on that basis building floors generally clear from the bottom upwards first provided there are no other contributing influences
- the direction of merge where flows are in adjacent directions may favour the floor flow over stair flow by as much as 70:30 for short periods, but overall 50:50 is the approximate default ratio
- of more importance is the time used in pre-movement activities, time that would otherwise be used for evacuation is lost and may be critical later (advice is therefore to begin evacuation as soon as the alarm sounds).

4.1 Realities of egress situations

In genuine egress situations where there is no perceived danger, crowd behaviour is expected to follow drill type behaviour because the evacuees are likely to just perceive it as another drill. However, if there is the presence of smoke and life-threatening conditions that behaviour may change. The premise is that deference behaviour at merge points that accounts for a 50:50 merging may give way to competitive behaviour, at least for the flow stream moving away from threatening conditions such as the fire. This aggression is likely to result in pushing, probably from only one direction, that may slow the merge and in extreme circumstances the flow comes to a virtual standstill. Conclusions reached are that:

- drills and experiments do not necessarily replicate true evacuations under emergency conditions and this phenomenon needs to be recognised as a significant factor
- post-emergency interviews can provide valuable data of what actually happens in real evacuations
- BMI is not a factor with people movement speeds in evacuations, but they are probably moving slower with frequent stops due to congestion so are not really stretched physically. However, they may need places to rest (such as refuge areas) in the event of long evacuation paths

- another factor may be the increased size of people simply taking up more space and therefore reducing the effective flow rate even if the speed of movement is not altered (Collier 2008)
- even in extreme circumstances where pedestrian flows at the merge points may virtually come to a standstill, the flow downstream will still move ahead leaving a gap for the choked flow to fill the gap and move again, relieving the choke albeit momentarily.

Due to the natural ebb and flow of an evacuation situation, choking/merging is unlikely and any early development of such will naturally be dissipated in all but the most extreme circumstances of panic/aggression when there is a threat to life.

So is it a case of doing everything else right and there is no real problem? (That is, avoid panic and aggression and then evacuation is more likely to follow the rules/modelling on which schemes and designs are based?)

The problem of congestion due to merging during evacuations can be mitigated by employing fire engineering design and management solutions such as:

- staged evacuations where the most at risk floors (from fire) are evacuated first by:
    - using a Voice Communication System to inform (and provide reassurance to) occupants of the emergency and organise more effective evacuations that make the best use of fire evacuation time. At present voice communication is only required in sleeping purpose groups SC, SD, SA in buildings >25 m in height and the maximum occupant load is >40
- providing smoke lobbies just before protected stairwells and refuge areas for those people not able to move as quickly or just need a place to rest momentarily.
- sizing the protected stairwells so that they will hold all building occupants relatively safely while an evacuation proceeds.
- considering that the capacity of stairwells may only need to be a percentage of the capacity of a building on the basis that it is unlikely to be fully occupied at any given time.

4.2 Egress modelling

Egress modelling generally assumes that flow proceeds smoothly without necessarily accounting for congestion and resultant choking. However it is possible to introduce effects of competitive behaviour resulting from a particular stream pushing harder, perhaps due to threatening conditions behind them or just frustration due to lack of movement. Conclusions reached are that:

- modelling showed that the mode of merging (or merge ratio) at entry to stairwells only has a marginal effect on overall evacuation times from large buildings and only dictated which floors clear first
- the significant finding was that the evacuation times from individual floors were affected by the merging (ratio stair:floor) flow (and more significantly the clearance rate from certain floors could be seriously delayed)
- by modelling (various models) the merge ratio was shown not to have any meaningful influence on the total evacuation time of a building. This premise ignores the prospect of choking at merge points such as where floor flow meets stair flow. Choking may result if one or both streams are pushing harder due to

a real or perceived danger (possibly life-threatening) behind them. In this case deference behaviour, otherwise creditable to roughly 50:50 merging, may give way to more competitive behaviour as the perception of danger dominates.

5. RECOMMENDATIONS

It has been shown that merging at stair:floor junctions is not the problem on its own, but more the circumstance when flow channels combine and reduce the flow in upstream parts.

No conclusive evidence was found that **choking flow** at merging is very common or that it has a discernable effect on total building evacuation time. The only exceptions to this may be when people feel threatened (resulting in pushing and crushing) and here no amount of reassurance will help much. Prevention of such conditions developing will therefore always be the preferred solution.

5.1 Practical advice and solutions

Easily implementable practical solutions that are effective in limiting the conditions that would lead to congestion (and anxiety among occupants) are most likely the preferred measures. It is fortunate that many of them are already required or recommended in C/AS1, accompanying regulations and just plain fire safety education. This study reinforces the following measures.

Evacuation strategies:

- possibly extend the requirement of alarm types as in DBH (2005) Table 4.1/1 to Table 4.1/8 to include Type 8 (Voice Communication Systems) from just sleeping purpose groups SC, SD, SA, SR to include tall buildings (>58 m) where choking due to merging is more likely, such as in the WL purpose group range that includes business offices
- implement evacuation plans for large buildings managing and informing via public address systems ("this is not a drill" would be an important message), thus reducing pre-movement time
- have staged evacuations aimed to clear fire floor(s) where occupants are in immediate danger first
- evacuation plans coupled with voice communication will make the most effective use of the time available for pre-movement activities by initiating egress earlier, reducing the likelihood of evacuations in untenable conditions
- make use of elevators for evacuation of less mobile and disabled occupants who may otherwise impede stair flow
- note that alarm Type 13 (pressurisation of safe paths – stairways) is generally required for tall buildings exceeding 25 m depending on purpose group as in accordance with DBH (2005) Table 4.1 as above, with the intention of making a stairway a safe haven.

Safe havens:

- stairway capacity wide enough to hold flow equivalent to the whole floor occupancy
- make stairwells a safe haven (large enough capacity, pressurised, surface linings as currently required in accordance with the interior surface requirements relating to exitways in DBH (2005) Table 6.2), so that once occupants have reached the stairs they are relatively safe from the effects of smoke and fire
- consider the building may not be occupied to full capacity anyway at time of emergency, so the aim is to cater for say 70% full (need to justify on a statistical basis)

- provide smoke lobbies or refuge areas where evacuees, in particular those less mobile, can rest out of the main flow path and not impede stair flow.

Education:

- finally, educate population at large that a fire alarm means get out even if you think it is only a drill. This is an age-old message, the importance of which has never diminished over the decades: “just leave the building”.

Catering for extraordinary events such as a bomb threat in an unspecified location within a building would call for an entire building evacuation and a staged evacuation scheme would not necessarily be the best solution. Such an event is outside the scope of this study.

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Appendix B NEW ZEALAND COMPLIANCE DOCUMENTS CVM/1 AND C/AS1

B.1 Definitions, purpose groups and occupant loads

Non-combustible Materials shall be classified as *non-combustible* or *combustible* when tested to AS 1530 Part 1.

Notional boundary The *boundary* which for *fire* safety purposes, is assumed to exist between two *buildings* on the same property under a single land title.

COMMENT:
A *notional boundary* may be located anywhere between the two *buildings*, and once chosen determines the *unprotected area* permitted in each *building*. Locating it closer to one *building* than the other, may be an advantage where it is planned for a rear wall without windows to face the front wall of the other *building* requiring windows.

Occupant load The greatest number of people likely to occupy a particular space within a *building*. It is determined by:

a) multiplying the number of people per m^2 (occupant density) for the activity being undertaken, by the total floor area, or

b) for sleeping areas, counting the number of beds, or

c) for fixed seating areas, counting the number of seats.

Occupied space Any space within a *building* in which a *person* will be present from time to time during the *intended use* of the *building*.

Open path That part of an *escape route* (including *dead ends*) within a *firecell* where occupants may be exposed to *fire* or smoke while making their escape.

Open space includes land on which there is and will be no *buildings* and which has no roof over any part of it other than overhanging eaves.

Other property means any land or *buildings* or part of any land or buildings, that are:

a) not held under the same *allotment*; or

b) not held under the same *ownership*; and includes a *road*.

Owner in relation to any land and any *buildings* on that land:

a) means the *person* who:

i) is entitled to the rack rent from the land

ii) would be so entitled if the land were let to a tenant at a rack rent; and

b) includes:

i) the *owner* of the fee simple of the land; and

ii) any *person* who has agreed in writing, whether conditionally or unconditionally, to purchase the land or any leasehold estate or interest in the land, or to take a lease of the land and is bound by the agreement because the agreement is still in force. Amend 4 Oct 2005

Penetration A pipe, cable or duct passing through an opening in a *fire separation*.

Person with a disability means a *person* who has an impairment or a combination of impairments that limits the extent to which the person can engage in the activities, pursuits, and processes of everyday life, including, without limitation, any of the following:

a) a physical, sensory, neurological, or intellectual impairment

b) a mental illness. Amend 4 Oct 2005

Person includes the Crown, a corporation sole, and also a body of *persons*, whether corporate or unincorporated.

Pitch line The line joining the leading edge or *nosings* (if any) of successive stair treads within a single flight of a *stairway*.

Primary element A *building element* providing the basic loadbearing capacity to the structure, and which if affected by *fire* may initiate instability or premature structural collapse.

COMMENT:
Suspended floors in multi-storey *buildings* are *primary elements*. Amend 4 Oct 2005

Amend 5 Oct 2005 exhaustive. Paragraph 5.6.12 describes the circumstances in which the *fire hazard category* may be reduced if the *FHC* 4 *purpose group* comprises only a small proportion of the *firecell*.

2.3 Occupant Load

2.3.1 The size and location of *escape routes* and the *fire safety precautions* applied to them in a *building* are related to the *occupant load*.

2.3.2 The *occupant load* is determined from the *purpose group* and number of people in each space of the *building*, and may need to be evaluated not only for each *purpose group*, but also for:

a) A space or open floor area involving one or more activities.

b) A floor containing more than one *purpose group*.

c) A single *firecell*.

d) Each floor within a *firecell*.

2.3.3 *Occupant loads* may be calculated from the occupant densities given in Table 2.2 based on the floor area of the part of the *building* housing the activity. Where a *building* space has alternative activity uses, the activity having the greatest occupant density shall be used. For an activity not specifically described in Table 2.2, the nearest reasonable description should be used.

COMMENT:

When using Table 2.2 to calculate the *occupant load* note that:

a) The floor area to be used is the total *firecell* floor area (except where Paragraph 2.3.4 applies) including that occupied by internal partitions and permanent *fixtures*.

b) Table 2.2 occupant densities already allow for a proportion of the floor area, appropriate to the activity, being occupied by furniture, partitions, *fixtures* and associated equipment.

2.3.4 Duplication should be avoided by:

a) Ensuring that where people may be involved in more than one activity, they are counted only once, and

b) Not including an *occupant load* for *exitways*, lift lobbies, sanitary facilities etc, used intermittently by people already counted elsewhere in the *building*.

Fixed seating

2.3.5 *Occupant load* assessment shall take account of the actual arrangement and number of seats for fixed seating (see Paragraph 3.9.3). Where additional floor area abuts the fixed seating, additional occupants may be allowed for based on standing space density, provided the *escape route* is not obstructed.

Where occupancy is based on number of beds

2.3.6 In *purpose groups* SC, SD and SA, the actual number of beds shall be used for determining the number of occupants.

COMMENT:

1. In this acceptable solution the term "beds" is used to denote the number of people expected to be sleeping in the *firecell*. Therefore, a double bed counts as two beds, and a tier of three single bunks (one above another) counts as three beds.

2. The number of beds depends on the individual layout in every case. Clearly dormitories will have a far greater number of beds within any given area than single bedrooms in a hospital or an old people's home, which may have individual lounge areas, toilets and kitchenettes attached. During use, the number of bed spaces must not be increased beyond that initially provided for unless a new *building consent* is obtained.

Justification for exceptions

2.3.7 Where, for a particular situation, the *occupant load* derived from Table 2.2 is clearly more than that which will occur, the basis of any proposal for a lesser *occupant load*, shall be substantiated to the *territorial authority*.

COMMENT:

Designing a *building* for a reduced *occupant load* can severely restrict future occupancy options, and may involve significant expense in meeting the means of escape provisions for increased numbers.

Amend 5 Oct 2005

Table 2.1: Purpose Groups
Paragraphs 1.3.4, 2.1.3, 2.2.1, 2.2.10, 5.6.11 and 5.6.13

Purpose group	Description of intended use of the building space	Some examples	Fire hazard category
CROWD ACTIVITIES			
CS or CL	For *occupied spaces*. CS applies to *occupant loads* up to 100 and CL to *occupant loads* exceeding 100.	Cinemas when classed as CS, art galleries, auditoria, bowling alleys, churches, clubs (non-residential), community halls, court rooms, dance halls, day care centres, gymnasia, lecture halls, museums, eating places (excluding kitchens), taverns, enclosed grandstands, indoor swimming pools.	1
		Cinemas when classed as CL, schools, colleges and tertiary institutions, libraries (up to 2.4 m high book storage), nightclubs, restaurants and eating places with cooking facilities, *early childhood centres theatre* stages, opera houses, television studios (with audience).	2
		Libraries (over 2.4 m high book storage).	3
CO	Spaces for viewing open air activities (does not include spaces below a grandstand).	Open grandstands, roofed but unenclosed grandstand, uncovered fixed seating.	1
CM	Spaces for displaying, or selling retail goods, wares or merchandise.	Exhibition halls, retail shops.	2
		Supermarkets or other stores with bulk storage/display over 3.0 m high.	4
SLEEPING ACTIVITIES			
SC	Spaces in which *principal users* because of age, mental or physical limitations require special care or treatment.	Hospitals. Care institutions for the aged, children, *people with disabilities*.	1
SD	Spaces in which *principal users* are restrained or liberties are restricted.	Care institutions, for the aged or children, with physical restraint or detention. Hospital with physical restraint, detention quarters in a police station, prison.	1
SA	Spaces providing transient accommodation, or where limited assistance or care is provided for *principal users*.	Motels, hotels, hostels, boarding houses, clubs (residential), boarding schools, dormitories, halls, *wharenui*, community care institutions.	1
SR	Attached and multi-unit residential dwellings.	*Multi-unit dwellings* or flats, apartments, and includes *household units* attached to the same or other *purpose groups*, such as caretakers' flats, and residential accommodation above a shop. *Household unit firecells* may contain garages which are used exclusively by the occupants of that *household unit*.	1
SH	Detached dwellings where people live as a single household or family.	Dwellings, houses, being *household units*, or *suites* in *purpose group* SA, separated from each other by distance. Detached dwellings may include attached self-contained *suites* such as granny flats when occupied by a member of the same family, and garages whether detached or part of the same *building* and are primarily for storage of the occupants' vehicles, tools and garden implements.	1

Amend 4 Oct 2005

Errata Jul 2001

Table 2.1: Purpose Groups *(continued)*

Purpose group	Description of intended use of the building space	Some examples	Fire hazard category
WORKING, BUSINESS OR STORAGE ACTIVITIES			
WL	Spaces used for working, business or storage – low *fire load*.	Manufacturing, processing or storage of *non-combustible* materials, or materials having a slow heat release rate, cool stores, covered cattle yards, wineries, grading or storage or packing of horticultural products, wet meat processing.	1
		Banks, hairdressing shops, beauty parlours, personal or professional services, dental offices, laundry (self-service), medical offices, business or other offices, police stations (without detention quarters), radio stations, television studios (no audience), small tool and appliance rental and service, telephone exchanges, dry meat processing.	2
WM	Spaces used for working, business or storage – medium *fire load* and slow/medium/fast *fire* growth rates (e.g. <1 MW in 75 sec) **(Note 1)**.	Manufacturing and processing of *combustible* materials not otherwise listed, including bulk storage up to 3 m high (excluding *foamed plastics*).	3
WH	Spaces used for working, business or storage – high *fire load* and slow/medium/ fast *fire* growth rates (e.g. <1 MW in 75 sec) **(Note 1)**.	Chemical manufacturing or processing plants, distilleries, feed mills, flour mills, lacquer factories, mattress factories, rubber processing plants, spray painting operations, plastics manufacturing, bulk storage of *combustible* materials over 3 m high (excluding *foamed plastics*).	4
WF	Spaces used for working, business or storage – medium/ high *fire load* and ultra fast *fire* growth rates (e.g. >1 MW in 75 sec) **(Note 1)**.	Areas involving significant quantities of highly *combustible* and flammable or explosive materials which because of their inherent characteristics constitute a special *fire hazard*, including: bulk plants for flammable liquids or gases, bulk storage warehouses for flammable substances, bulk storage of *foamed plastics*.	4 (The critical factor in this *purpose group* is the rate of *fire* growth.)
INTERMITTENT ACTIVITIES			
IE	*Exitways* on *escape routes*.	*Protected path, safe path.*	1
IA	Spaces for intermittent occupation or providing intermittently used support functions – low *fire load*.	Car parking, garages, carports, enclosed corridors, unstaffed kitchens or laundries, lift shafts, locker rooms, linen rooms, open balconies, *stairways* (within the *open path*), toilets and amenities, and service rooms incorporating machinery or equipment not using solid-fuel, gas or petroleum products as an energy source **(Note 2)**.	1
ID	Spaces for intermittent occupation or providing intermittently used support functions – medium *fire load*.	Maintenance workshops and service rooms incorporating machinery or equipment using solid-fuel, gas or petroleum products as an energy source **(Note 2)**.	3

Notes:

1. Refer to NFPA 92B for more information on *fire* growth rates.
2. Service rooms are spaces designed to accommodate any of the following: boiler/plant equipment, furnaces, incinerators, refuse, caretaking/cleaning equipment, airconditioning, heating, plumbing or electrical equipment, pipes, lift/escalator machine rooms, or similar services.

Table 2.2: Occupant Densities
Paragraphs 2.3.3 and 2.3.7

Activity	Occupant density (Users/m²) (see **Note 1**)
CROWD ACTIVITIES	
Airports – baggage claim	0.5
Airports – concourses	0.1
Airports – waiting areas, check in	0.7
Area without seating or aisles	1.0
Art galleries, museums	0.25
Bar sitting areas	1.0
Bar standing area	2.0
Bleachers, pews or similar bench type seating	2.2 users per linear metre
Classrooms	0.5
Dance floors	1.7
Day care centres	0.25
Dining, beverage and cafeteria spaces	0.8
Exhibition areas, trade fairs	0.7
Fitness centres	0.2
Gymnasia	0.35
Indoor games areas/bowling alleys, etc	0.1
Libraries – stack areas	0.1
Libraries – other areas	0.15
Lobbies and foyers	1.0
Mall areas used for assembly purposes	1.0
Reading or writing rooms and lounges	0.5
Restaurants, dining rooms and lounges	0.9
Shop spaces and pedestrian circulation areas including malls and arcades	0.3
Shop spaces for furniture, floor coverings, large appliances, building supplies and manchester	0.1
Showrooms	0.2
Space with fixed seating	as number of seats (see **Note 2**)
Space with loose seating	1.3
Spaces with loose seating and tables	0.9
Stadia and grandstands	1.8
Stages for theatrical performances	1.3
Standing space	2.6
Swimming pools (water surface area)	0.2
Swimming pool surrounds and seating	0.35
Teaching laboratories	0.2
Vocational training rooms in schools	0.1

Table 2.2: Occupant Densities *(continued)*

Activity	Occupant density (Users/m²) (see **Note 1**)
SLEEPING ACTIVITIES	
Bedrooms Bunkrooms Detention quarters Dormitories, hostels Halls and *wharenui* (**Note 5**) Wards containing more than two beds	as number of beds (see **Note 2**)
WORKING BUSINESS AND STORAGE ACTIVITIES	
Aircraft hangars	0.02
Bulk storage (e.g. solid stacked)	0.01
Commercial laboratories, laundries	0.1
Computer rooms (not used as classrooms for training)	0.04
Factory space in which layout and normal use determines the number of people using it in working hours	as approved (see **Note 3**)
Heavy industry	0.03
Interview rooms	0.2
Kitchens	0.1
Manufacturing and process areas, staffrooms	0.1
Offices and staffrooms	0.1
Personal service facilities	0.2
Reception areas	0.1
Workrooms, workshops	0.2
Warehouse storage (e.g. racks and shelves)	0.03
INTERMITTENT ACTIVITIES	(see **Note 4**)
Boiler rooms, plant rooms, service units and maintenance workshops	0.03
Parking *buildings*, garages	0.02
Exitways, enclosed corridors, lifts (no occupants counted)	0.0
Laundry and house keeping facilities	0.2
Storage	0.02
Toilets and subordinate spaces (no occupants counted)	0.0

Notes:

1. The floor area to be used shall be the total *firecell* floor area including that occupied by internal partitions and *fixtures*. The occupant densities in this table already allow for a proportion of floor area, appropriate to the activity, being occupied by furniture, partitions, *fixtures* and associated equipment.
2. For fixed seating and beds, the number of seats or beds is used instead of an occupant density (users per m²).
3. In such cases, the *occupant load* must be specified when seeking a *building consent*. Future increase in numbers shall be treated as a change of use.
4. Spaces for intermittent activities (*purpose groups* IE, IA, ID), are normally not assessed for *occupant load*. It is assumed that the occupation is temporary and by people who would already have been included in the *occupant load* of another space. The figures given in the table apply where people are specifically employed to perform the functions for which the spaces are provided.
5. For halls and *wharenui*, the maximum *occupant load* is determined by the *fire safety precautions* and the escape capacity. See Paragraphs 3.3.2 h), 3.4.2 e), 6.7.2 and 6.7.9.

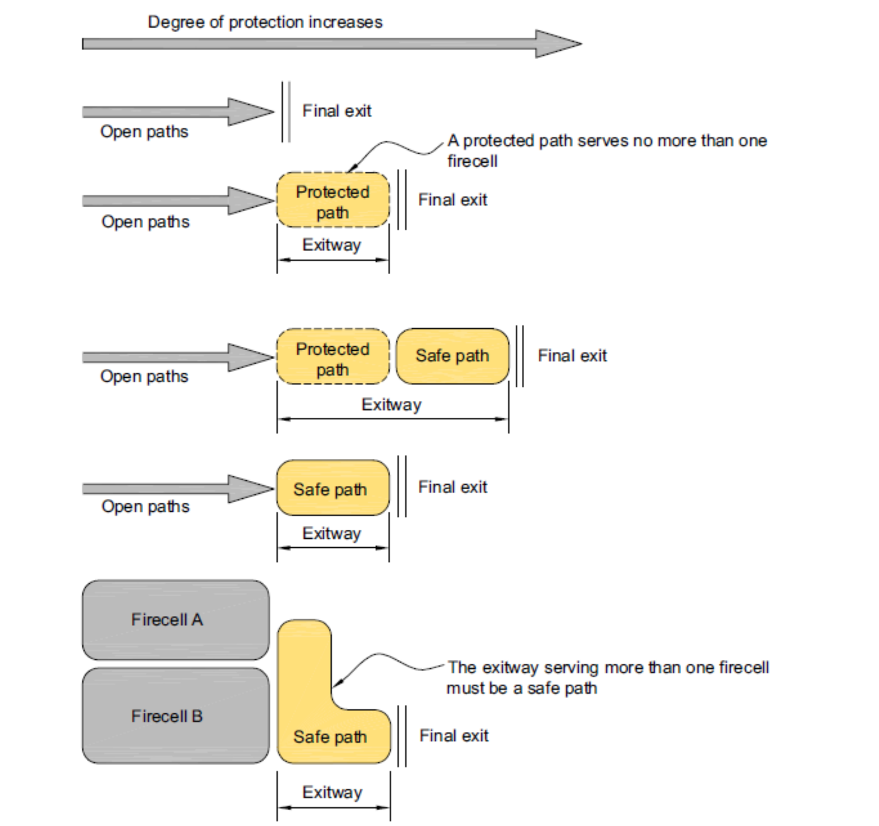
B.2 Means of escape

Acceptable Solution C/AS1 Part 3: Means of Escape

3.1 General Principles

3.1.1 All *buildings* shall have *means of escape from fire* which, include *escape routes*. An *escape route* (see Figure 3.1) shall provide *adequate* protection to any occupant escaping to a *safe place* from a *fire* within a *building*.

Figure 3.1: Escape Routes
Paragraphs 3.1.1 and 3.1.2



Note:
The *final exit* is where the *escape route* enters a *safe place*. This might be beyond the exit door from the *building*

3.1.2 Components of an *escape route* in ascending order of protection are the *open path, protected path, safe path* and *final exit* (see Figure 3.1). Depending on the total *travel distance*, one or more of these components are necessary. An *escape route* shall not pass from a higher to lower level of protection in the direction of escape.

3.1.3 Provided the allowable lengths of *open paths* and *protected paths* are not exceeded, an *escape route* may comprise only an *open path* (or *open path* and *protected path*) and *final exit*.

3.1.4 *Escape routes* shall comply with NZBC Clause D1.3.3 Access Routes. Ramps, stairs, ladders, landings, *handrails*, doors, vision panels and openings shall comply with D1/AS1, except that dispensations may be allowed for windows, as described in Paragraph 3.18.

Advantages of FSPs

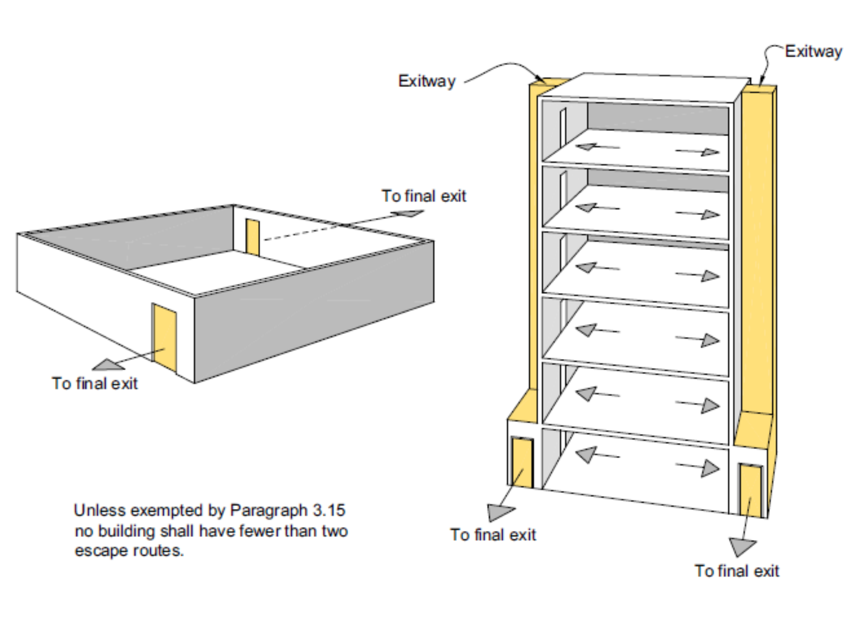
3.1.5 Advantages in the size and *construction* of both *firecells* and *escape routes* may be gained by the use of *fire safety precautions* involving smoke detectors, heat detectors and sprinklers. Table 4.1 describes circumstances where such *FSPs* are mandatory. Paragraph 3.5 describes permitted increases in *open path* length for specific *purpose groups* where one or more of those *FSPs* are installed.

3.2 Number of Escape Routes

3.2.1 Except where Paragraph 3.15 allows the use of single *escape routes*, every *occupied space* in a *building* shall be served by two or more *escape routes* (see Figure 3.2).

3.2.2 Table 3.1 gives the minimum number of *escape routes* needed for a given *occupant load*.

Figure 3.2: Minimum Number of Escape Routes
Paragraph 3.2.1



3.3 Height and Width of Escape Routes

Height

3.3.1 Within *escape routes:*

a) The clear height shall be no less than 2100 mm across the full width, except that isolated ceiling fittings not exceeding 200 mm in diameter may project downwards to reduce this clearance by no more than 100 mm, and

b) Any *smoke control door* or *fire door* opening within, or giving access to any *exitway*, shall have a clear height of no less than 1955 mm for the required width of the opening.

Width

3.3.2 Widths of *escape routes* shall be no less than required by Table 3.2 for both the width of individual *escape routes*, and the total combined width of all available *escape routes*, but:

a) **Exitways**. The width of an *escape route* within an *exitway* shall be no less than 1000 mm.

b) **Provision for unusable escape route.** Except where *dead ends* and single *escape routes* are permitted, in unsprinklered *firecells* the total required width shall still be available should one of the *escape routes* be unusable due to the location of the *fire* or any other reason (see Figure 3.3).

COMMENT:

1. This may be achieved either by providing additional *escape routes* or by making the minimum required number wider.
2. This means that where two *escape routes* are required by Table 3.1, and no additional *escape route* is provided, each *escape route* shall be sized for the required total width. Similarly, if the table requires three *escape routes*, and no additional *escape route* is provided, widths shall be chosen to ensure that any two *escape routes* provide the required total width.

c) **Sprinkler concession.** Where the *firecell* is sprinklered it is unnecessary to provide extra width to allow for the possibility that one *escape route* may be unusable.

d) **Horizontal escape routes.** A horizontal *escape route* which has a single direction of escape shall be wide enough at any point to take the full *occupant load* from all contributing *occupied spaces*, but the *escape route* may have its width progressively increased as it passes the exit from each *occupied space* (see Figure 3.4).

e) A horizontal *escape route* with two directions of escape, shall, for its full length, have sufficient width to allow for the *occupant load* from all contributing spaces. This shall not apply where Paragraph 3.9.12 e) applies for escape through adjacent *firecells.*

f) **Intermediate floors.** In *firecells* containing *intermediate floors*, both the vertical and horizontal parts of the *open path escape route* shall be wide enough to take the full *occupant load* from all contributing spaces.

g) **Vertical safe paths**. Vertical *safe paths* serving *firecells* at more than one level shall have minimum widths at any point determined only by the largest total *occupant load* from any level passing that point in the direction of escape.

COMMENT:
It is not necessary to provide for cumulative *occupant load* as the *escape route* passes each floor level.

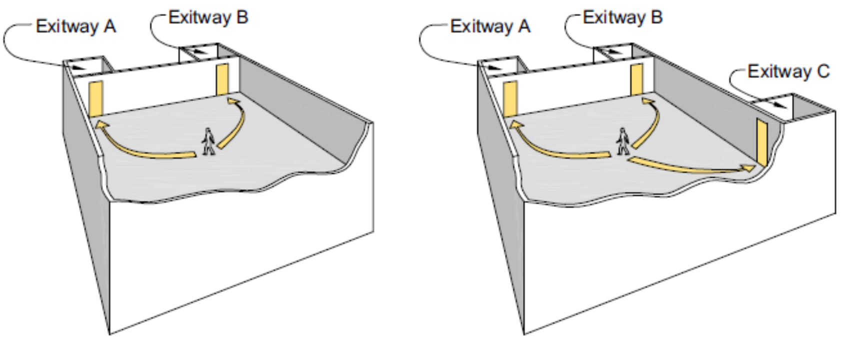
h) **Wharenui.** In *wharenui* where the *surface finishes* of the interior walls do not comply with Paragraphs 6.20.1 to 6.20.7, the *escape route* widths required by Table 3.2 shall be doubled.

i) **Basements.** Where an *escape route* from upper floors is joined at the level of a *final exit* by an *escape route* from a *basement* or lower floors, the *escape route* width at the point they combine shall be increased to accommodate the *occupant loads* from both directions (see Figure 3.5).

j) **Ladders.** The width requirements of Table 3.2 do not apply to ladders (see Paragraph 3.10.2).

k) **Fixed or loose seating.** The width requirements of Table 3.2 do not apply to fixed or loose seating (see Paragraphs 3.9.3 and 3.9.10).

Figure 3.3: Exitway Widths in Unsprinklered Firecells
Paragraph 3.3.2 b)



Exitways A and B each wide enough to take the full occupant load.

The combined width of any two exitways shall be sufficent to take the full occupant load.

Figure 3.4: Increase in Width for Horizontal Escape Routes Having a Single Direction of Escape
Paragraph 3.3.2 d)

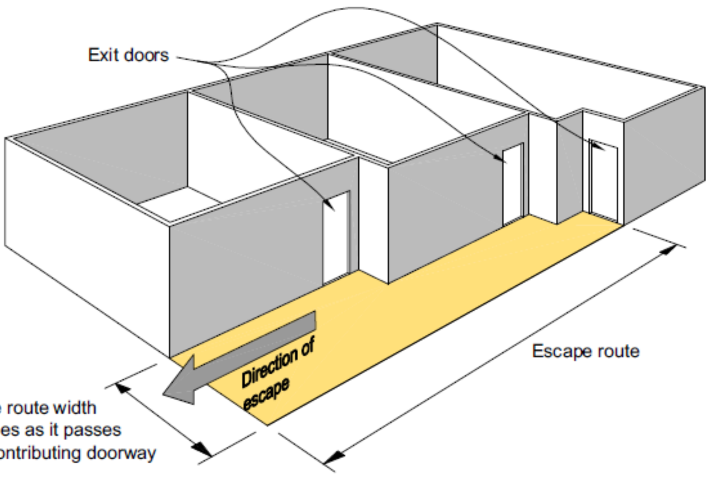
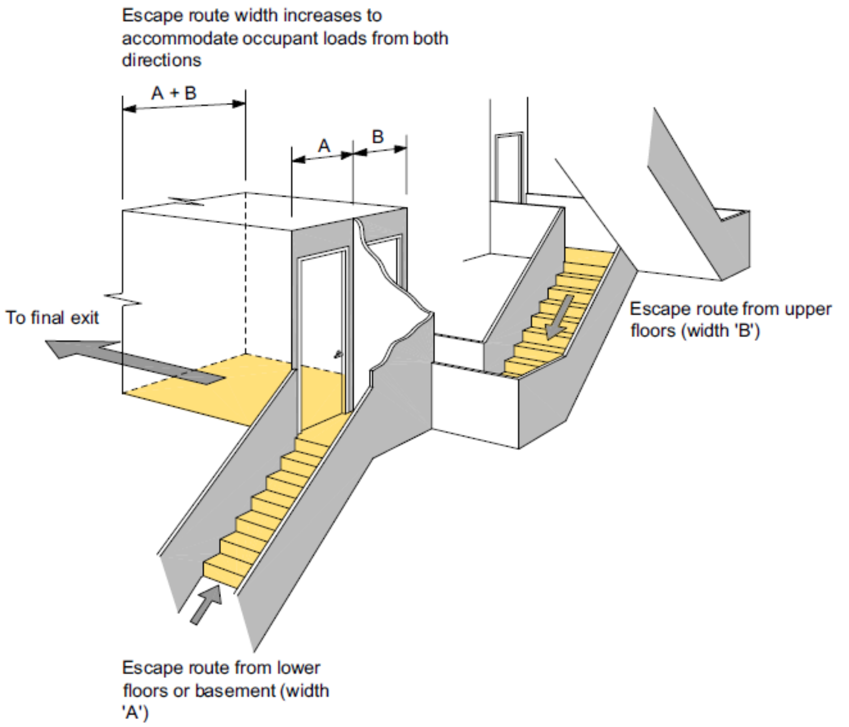


Figure 3.5: Escape Routes from Lower and Upper Floors
Paragraph 3.3.2 i)



Handrails and limitations to stair widths

3.3.3 For safe evacuation on stairs:

a) *Stairways* in *escape routes* wider than 1500 mm shall have *handrails* on both sides.

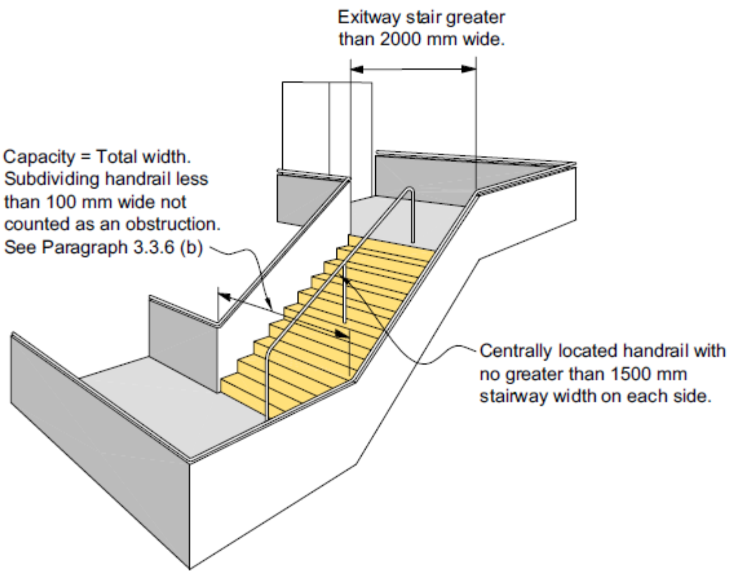
b) *Stairways* in *escape routes* wider than 2000 mm (see Figure 3.6) shall be provided with intermediate *handrails*, equally spaced, and providing a width not greater than 1500 mm for each section of the *stairway*.

COMMENT:
D1/AS1 Paragraph 6.0, requires all *stairways* to have at least one *handrail*, and for *accessible* stairs, *handrails* are required on both sides.

3.3.4 Where the *escape height* exceeds 34 m, no more than 1500 mm shall be credited to the width of any *stairway* in an *escape route*.

COMMENT:
1. *Stairway* width may be more than 1500 mm, but for the calculation of stair capacity, not more than 1500 mm may be used.
2. This may require the provision of additional *exitways* to carry the *occupant load*, which allows for a more orderly evacuation than might occur with people trying in panic to pass one another on a wider *stairway*.

Figure 3.6: Limitations to Stair Widths
Paragraph 3.3.3 b)



Curved and spiral stairs

3.3.5 Where curved or spiral stairs form part of an *escape route*, the required width shall be that described as "walking area" in D1/AS1 Figure 17.

Obstructions

3.3.6 Except as permitted by Paragraph 3.17.7, *escape routes* shall not be obstructed by access control systems such as revolving or automatic sliding doors, chains, turnstiles, sliding bars, crowd control barriers and similar devices.

The following minor obstructions are acceptable within the width of an *escape route*.

a) **Minor projections** complying with the requirements of D1/AS1 such as signs, switches, alarm sounders and similar projections.

b) ***Handrails*** complying with D1/AS1, projecting not more than 100 mm into the width, and *handrails* subdividing wide *stairways*, that reduce the width by no more than 100 mm (see Paragraph 3.3.3).

COMMENT:

1. The term "clear width" as used in D1/AS1 has the same meaning as the word "width" in this acceptable solution (including Table 3.2). This means that where *handrails* are used on both sides of an *exitway* having a "width" of 1000 mm, the measured width between faces of the *handrails* must be no less than 800 mm.
2. For *accessible* and common *stairways*, D1/AS1 requires the width between faces of the *handrails* to be no less than 900 mm, however, this is not necessary in vertical *safe paths* where refuge areas are provided.

c) **Fixed seating** (at the start of an *escape route*) which complies with the requirements of Paragraph 3.9.3 and Table 3.4 for the width of aisles and space between rows.

d) **Windows** complying with the special conditions of Paragraph 3.18 for use as part of an *escape route*.

e) **Door assemblies** which reduce the width of an *exitway* by no more than 125 mm when the door is fully open (see Figure 3.25).

COMMENT:
The measured width with the door open must be no less than the required *exitway* width minus 125 mm, this allowance is for projecting parts of the door frame assembly, the thickness of the door when open and similar acceptable obstructions.

Accessible escape routes

3.3.7 Where an *accessible route* is also used as an *escape route*, the width shall be no less than required by D1/AS1 for *accessible routes*. However, any part of the *open path*, not required to be an *accessible route* for normal daily activities, shall have a minimum width of 850 mm, and any doors on the *escape route* shall open in the direction of escape.

COMMENT:
1. Paragraph 3.17.5 already requires a minimum door opening width of 760 mm on *open paths*.
2. The minimum 1200 mm width for *accessible routes*, as given in D1/AS1, assumes sufficient width for an ambulant *person* to pass a *person* in a wheelchair. It is assumed that all people will be travelling in the same direction during an evacuation and passing provision is not necessary.
3. The minimum width of an *escape route* within an *exitway* is 1000 mm (Paragraph 3.3.2 a)). However, the minimum width is 1200 mm where that *exitway* is required to be an *accessible route* for normal daily activities.

3.4 Length of Escape Routes

3.4.1 An *escape route* may be any length, but:

a) The lengths of *dead ends*, total *open paths* and *protected paths* shall not exceed those permitted by Table 3.3, adjusted as necessary for:

i) reductions on *intermediate floors* (see Paragraph 3.4.6),

ii) reductions on stairs and ladders (see Paragraph 3.4.7),

iii) increases allowed for *fire safety precautions* (see Paragraph 3.5), and

COMMENT:
Table 3.3 limits the *dead end* length to 24 m in *purpose group* SH. This means that in large two floor, or in three floor detached dwellings, it may be necessary to have two means of escape or install a *fire safety precaution* which permits an increase in *open path* length allowed by Paragraph 3.5.

b) Where the distance to the *final exit* exceeds the allowable combined length for total *open path* plus *protected path*, the remainder of the *escape route* shall be a *safe path*. (See Paragraph 3.11.7 for *safe path* length restrictions within a single floor level.)

Open paths

3.4.2 When determining *open path* lengths, including the *dead end*:

a) **Start point.** The length is measured from no more than 1.0 m from the most remote point in a space.

b) **Multiple purpose groups.** The lengths in Table 3.3 apply to specific *purpose groups*. When different *purpose groups*, having different allowable maximum *open path* lengths use the same *open path*, the *purpose group* with the shortest maximum length shall apply.

c) **Furniture/fittings.** Allowance shall be made for the *travel distance* around obstructions such as furniture, fittings and office equipment located in the *open path* (see Figure 3.7).

d) **Multiple escape routes.** Where two or more *escape routes* are required, *open path* lengths from any point on a floor to no fewer than two exits from the *firecell* shall not exceed the lengths given in Table 3.3.

3.12.2 Other activities are permitted in a *safe path* if:

a) An alternative *escape route* is available from all *firecells* served by the *safe path* in which the activities occur, and

b) An alarm system is installed in the *safe path* and connected to alerting devices installed throughout the *building*. (A Type 4 alarm shall be used for *occupant loads* up to 500, and Type 7 for *occupant loads* exceeding 500), and

c) The *escape route* is not impeded by the other activity or the occupants involved in those other activities, and

d) Those activities:

i) have a *fire hazard category* of no greater than 1, and

ii) except in the case of *sanitary fixtures*, are visible to users of the *exitway*, and

iii) exist only to provide support functions to the activities of the *purpose group* served by the *exitway*.

COMMENT:
Other activities may include a reception counter, sweet stall, ticket office, toilet facilities etc. Storage of cloaks or linen, a cleaner's cupboard, or an electrical switchboard would not be permitted, and would need to be *fire separated*.

Lifts

3.12.3 A passenger lift, but not a goods lift, may be located in a vertical *safe path* containing a *stairway* provided all the following conditions are satisfied:

a) The lift shaft and all its openings are located entirely within a single *firecell* containing the vertical *safe path*.

b) Passenger access into and from the lift car takes place entirely within the *safe path*.

c) The *fire hazard category* of any *purpose group* served by the vertical *safe path* and lift is no more than 3.

d) No other activity occurs within the vertical *safe path*.

e) The lift machine room is a separate *firecell*, and the openings for lift ropes through the *fire separation* shall be as small as practicable, and any *penetrations*, such as for electrical cables, are *fire stopped*. See Paragraph 6.17 for *fire stopping* and Paragraph 6.10.1 for required *FRR*.

3.13 Refuge Areas

3.13.1 In vertical *safe paths* in tall *buildings*, where required by Table 4.1, refuge areas shall be located at intervals of no greater than every third floor above the lowest *final exit*, except that the topmost refuge area may be 4 floors below the highest occupied floor. In this context the highest occupied floor is as described in the definition of *building height*.

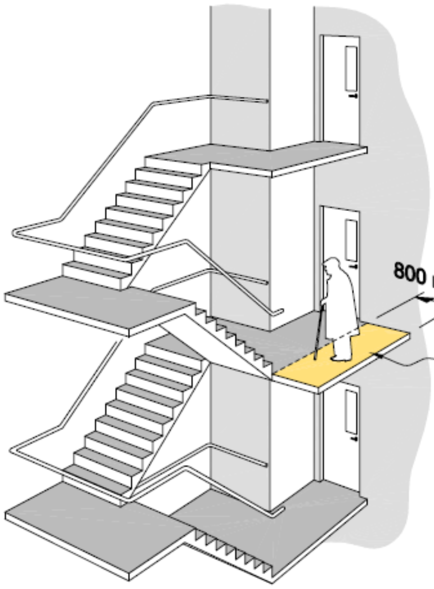
3.13.2 Refuge areas shall provide an additional space within the *safe path* no less than 800 mm wide and 2.0 m^2 in area, which shall not intrude into the specified width of the *escape route*, or be reduced by any door in, or opening into the *safe path* (see Figure 3.17). A refuge area shall:

a) Be located at the same level as the horizontal *escape route* it serves, and

b) Have the same level of *fire* protection (passive and active) as applies to the vertical *safe path* with which it is associated.

COMMENT:
Refuge areas are provided where congestion in the *safe path* may occur. They also allow slow moving *persons* to rest and others to pass.

Figure 3.17: Refuge Areas
Paragraph 3.13.2



3.14 External escape routes

3.14.1 Where an *escape route* enters a space exposed to the open air (e.g. an open *stairway*, a balcony, across a roof or a ground level path), it shall meet the requirements for a *safe path* between that point and the *final exit*. *Safe path* separation requirements shall be achieved by providing either distance or *fire* rated *construction* between the *escape route* and adjacent *firecells*, as provided for in Paragraphs 3.14.2 to 3.14.6.

COMMENT:
Balconies with one direction of escape comply with the requirements of a *safe path* if the *external wall* beside the balcony has no *unprotected areas* or the balcony is large enough to allow separation by distance from the *external wall* (see Paragraph 3.14.3). Balconies with two directions of escape from all *firecell* exits are also considered to be *safe paths*, even if the adjacent *external wall* has 100% *unprotected area*.

Separation by distance

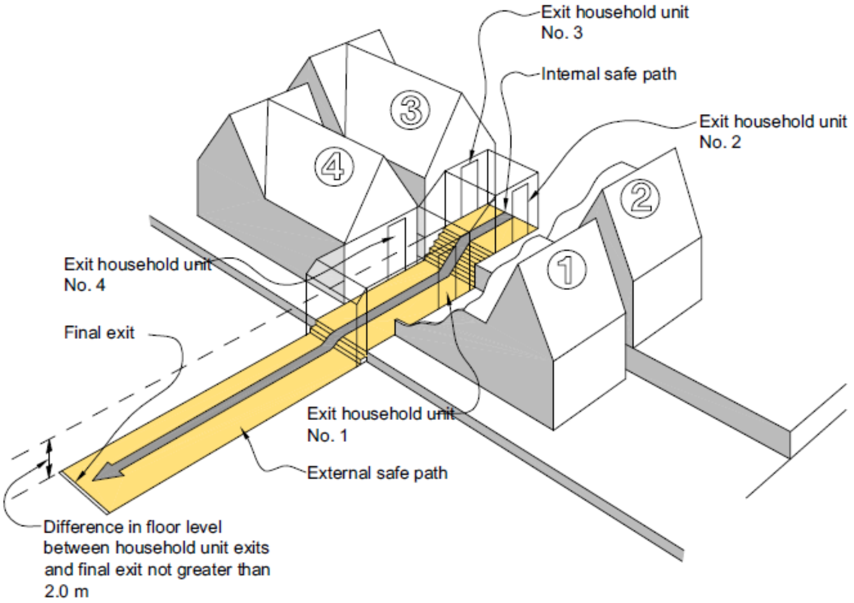
3.14.2 Separation by distance shall be achieved by:

a) Locating the *escape route* no less than the distance required by Paragraph 3.14.3 from *external walls*, or

b) Locating the *escape route* so that it diverges from *external walls* (see Paragraph 3.14.5 a)), or

c) Providing alternative directions of escape from the point where the *escape route* passes through an *external wall* and becomes an external *escape route* (see Paragraph 3.14.5 b)).

Figure 3.24: Single Escape Routes – Split Level Exitway
Paragraph 3.15.8



3.16 Special Conditions for Crowd and Sleeping Purpose Groups

Purpose group CL

3.16.1 Any *firecell* containing *purpose group* CL shall be served by *safe paths* or *final exits* connecting directly to that *firecell*. The number of *safe paths* shall comply with Table 3.1 for the *occupant load*.

3.16.2 Aisles and walkways between seats shall comply with Paragraphs 3.9.3 to 3.9.9.

Exitways from upper and intermediate floors in purpose group CL

3.16.3 Entrances to vertical *safe paths* shall be preceded by *protected paths* except where:

a) The *safe path* from an upper floor or *intermediate floor* serves only that floor, or

b) The *firecell* is sprinklered, or

c) The *occupant load* of the *firecell* is less than 150, or

d) *Fire safety precaution* Type 8 is installed and an approved staged evacuation scheme is operable.

COMMENT:

1. An upper floor is any floor above *final exit* level. See Paragraphs 3.4.3 and 3.4.5 for required *protected path* floor area.
2. With a staged evacuation scheme the *firecell* of *fire* origin is the first to be evacuated.

Final exit separation

3.16.4 *Final exits* which open onto the same *safe place*, shall be spaced no closer than 5.0 m centre to centre. This applies to both internal and external *exitways*.

COMMENT:

This provision allows quick dispersal and reduces the risk of a crowd blocking a *final exit*.

Open air auditoriums, purpose group CO

3.16.5 Open tiered seating decks shall:

a) Have the number of *exitways* required by Table 3.1 for the *occupant load*,

b) Comply with Paragraphs 3.9.3 to 3.9.9 for aisles, and walkways between seats (Table 3.4 permits seat numbers to be doubled in *purpose group* CO),

c) Have *exitways* spaced at no more than:

   i) 60 m apart where the space below the seating deck is required to be *fire separated* (see Paragraph 6.5), or

   ii) 20 m apart where the space below requires no *fire separation*, and

d) Be served by *escape routes* completely open to the air where the seating deck is not a *fire separation*.

3.16.6 Where the seating deck is required to be a *fire separation*, an *escape route* may pass though the deck and the space below, provided that part of the *escape route* is a *safe path* with a *FRR* based on no less than the *F rating* required for the lower space.

3.16.7 A grandstand in which the roof configuration, or *building elements* such as screens or partial glazing, restrict the escape of smoke and hot gases, shall, even if having a large open area, be classified in *purpose group* CL and not CO.

Purpose groups SC, SD, SA and SR

3.16.8 At least half the *safe paths* serving *purpose groups* SC and SD shall terminate in a *safe place* without being combined with an *escape route* from any other *purpose group*.

3.16.9 *Safe paths* serving *purpose groups* SA and SR may also serve other *purpose groups* where:

a) A single *escape route* complying with Paragraph 3.15 is permitted, or

b) Alternative *escape routes* which are *safe paths* are provided.

These requirements shall also apply to all *firecells* on lower floors using the same *escape routes*.

COMMENT:

Any *building* with sleeping *purpose groups* on upper floors is required by Paragraph 4.5.11 to have appropriate *fire* alarm systems on all lower floors.

3.17 Doors Subdividing Escape Routes

Door closers and latching

3.17.1 Except as permitted by Paragraph 3.17.7 (revolving doors, automatic doors and access control systems), doors into or within *exitways* shall satisfy all the following requirements by being:

a) Hinged or pivoted on one vertical edge only.

b) Self-closing, and the self-closing device shall be:

   i) active at all times, or

   ii) activated by releasing a *hold-open device* in response to operation of a smoke detector (see Paragraph 3.17.10), or

Table 3.1: Number of Escape Routes from a Floor Level
Paragraphs 3.2.2, 3.3.2 b), 3.16.1 and 3.16.5 a)

Occupant load on the floor being considered (Note 1)		Minimum number of escape routes
Purpose groups SC, SD		
Up to	50 beds	2
Over	50	2 plus **(Note 2)**
Purpose groups SA, SR		
Up to	100 beds	2
Over	100	2 plus **(Note 3)**
Purpose groups CS, CL, CO, CM, WL, WM, WF, WH, IA, ID		
Up to	500	2 **(Note 4)**
Up to	1000	3
Up to	2000	4
Up to	4000	5
Up to	7000	6
Up to	16,000	8
Over	16,000	8 plus **(Note 5)**

Notes:

1. Guidance on determining *occupant load* is given in Part 2. Special conditions applying to crowd and sleeping *purpose groups* are contained in Paragraph 3.16.
2. Plus 1 for every 100 beds, or part thereof over 50.
3. Plus 1 for every 100 beds, or part thereof over 100.
4. Special cases allowing single *escape routes* are given in Paragraph 3.15.
5. Plus 1 for every 5000, or part thereof increase in *occupant load,* above 16,000.

Table 3.2: Width of Escape Routes
Paragraphs 3.3.2, 3.3.2 h), j) and k), 3.3.6 b), 3.9.12 e)

	Purpose groups		
	CS, CL, CM, SA, SR, WL, WM, WH, WF, IA, ID	SC, SD	CO **(Note 9)**
	Minimum width of individual escape routes (mm)		
Horizontal travel Vertical travel **(Notes 7 and 8)**	850 **(Notes 1, 2, 3, 5)** 1000 **(Note 2)**	1200 1500 **(Note 4)**	1000 1200 **(Note 5)**
	Required total combined width of all escape routes (Note 6) (mm per person)		
Horizontal travel Vertical travel **(Notes 7 and 8)**	7 9	8 10	2 3
Column 1	2	3	4

Notes:

1. The width of an *escape route* within an *exitway*, excluding the entry door (see Paragraph 3.3.2 a)), shall be no less than 1000 mm.
2. Where there is no requirement to provide for *people with disabilities*, and the *occupant load* is less than 50, widths of *escape routes* when an *open path*, may be reduced to 700 mm for horizontal travel, and 850 mm for vertical travel.
3. For gangways between fixed storage in other than public areas, width may be reduced to 530 mm.
4. These widths apply only to *escape routes* from sleeping areas, but the width from column 2 may be used for *escape routes* serving only:
   a) Occupants of non-sleeping areas, or
   b) Sleeping areas where the number of beds is less than 10 and the occupants are active and can be directed by staff, or
   c) Occupants who are active, ambulant and require no assistance to escape.
5. For areas of fixed or loose seating:
   a) *Escape routes* shall comply with the requirements of Paragraphs 3.9.3 and 3.9.4 for aisles and width between rows.
   b) From the termination of an aisle the minimum *escape route* width shall be the greater of the aisle width or the width required by Paragraph 3.3.2.
6. The width calculated on *occupant load* determines any extra width required, but in no case shall the width be less than the minimum for individual *escape routes*.
7. For limitations on width of the *escape route* in *stairways* and where the *escape height* exceeds 34 m, see Paragraphs 3.3.3 and 3.3.4.
8. Ramps with a slope of not more than 1:8 may be regarded as horizontal travel.
9. The widths given in column 4 apply only to *escape routes* wholly in the open air. Any enclosed part of the *escape route* shall be the width determined for CL using column 2 and that width shall not be reduced even if the *escape route* subsequently passes to the open air.

Table 3.3: Lengths of Open Paths and Protected Paths
Paragraphs 1.3.4, 3.4.1 a), 3.4.2 b), d) and e), 3.4.4, 3.4.6, 3.4.8, 3.5.1, 3.5.2, 3.5.3, 3.5.6, 3.8.1, 3.9.7, 3.11.7, 3.15.1 b) and c), 3.15.5 c), 6.8.2 and Figures 3.7, 3.15 and 3.21

Type of path	Purpose groups				
	SC, SD **(Note 4)**	WF	CS, CL, CM, SA	WL, WM, WH, SR, SH	CO, IA, ID
	Maximum length (m)				
Dead end open path	18	12	18	24	36
Total open path (Note 5)	45	30	45	60	90
Protected path	45	30	45	60	90
Column 1	2	3	4	5	6

Notes:

1. Where the *occupant load* exceeds 50, there shall be two or more *escape routes* from any space.
2. In accordance with Paragraphs 3.5 and 3.11.7 *open path* lengths and horizontal *safe path* lengths (but not protected paths), may be increased by:

	SA, SR, SH	CS, CL, CM, WL, WM, WH, IA, ID
where heat detectors are installed	10%	20%
where sprinklers are installed	50%	100%
where smoke detectors Types 4, 5 or 7 are installed	50%	100%

3. Paragraph 3.5.6 gives the circumstances where permitted increases, in the lengths of *dead end* and total *open path* may be combined.
4. Because *purpose groups* SC and SD are required by Table 4.1 always to have sprinklers and smoke detectors, no increases in accordance with Paragraph 3.5 are permitted for those *purpose groups*.
5. Allowed only if there is more than one *escape route*, but shall include any initial *dead end* length.

Table 3.4: Walkways in Fixed Seating
Paragraphs 3.3.6 c), 3.9.3 b) and c), 3.16.5 b) and Figures 3.13, 3.14

Minimum walkway width (mm) (Note 1)	**Maximum number of seats in any row (Note 2)** Where one aisle only	Where aisles both sides
300	7	14
340	9	16
380	9	18
420	10	20
460	11	22
500	12	24

Notes:

1. The walkway width is measured between the foremost part of the seat and the backmost part of the seat in front of it.
2. For *purpose group* CO, the number of seats in a row may be doubled.

B.3 Requirements for firecells

4.4 Using Table 4.1

4.4.1 Table 4.1 is applied by following steps 1 to 9.

Step 1 Determine for each *firecell*:

a) The *purpose group* contained.

b) The primary *purpose group* (see Paragraph 2.2.2) where more than one.

c) The *occupant load* (includes all *purpose groups* in the *firecell*).

d) Whether it contains *intermediate floors*.

e) The *escape height* from the *firecell*.

Step 2 Choose the appropriate page of Table 4.1 for the *purpose group* and *occupant load* of the *firecell* being considered. Note that Tables 4.1/1 to Table 4.1/4 are for active *purpose groups* each applying to a different range of *occupant loads*. Table 4.1/5 for sleeping *purpose groups* is a single page with permitted *occupant load* variations being provided in the notes to the table.

Step 3 Select the horizontal panel for the appropriate *purpose group* as identified in the left hand column.

Step 4 From the top row of the table select the correct column for the *firecell escape height*.

Step 5 From that column note the required *F rating* and numbered *fire safety precautions* for the *firecell*.

Step 6 Using the key at the front of Table 4.1, identify the nature of the required *fire safety precautions* by reading the description beside each Type number. Note also any special applications identified by alphabetical suffixes in the table.

Step 7 Repeat the process for all *firecells* in the *building*.

Step 8 Determine the *fire safety precautions* for the whole *building* by applying the relevant provisions of Paragraph 4.5.

Step 9 Check whether the notes below Table 4.1 apply to the *firecell* being considered.

COMMENT:
In many cases the analysis of *fire safety precautions* will produce different requirements for different *firecells* in the *building*. It is for the *owner* to decide the most practical arrangement that satisfies the requirements both for individual *purpose groups* and the *building* as a whole.

4.5 Determining FSPs for Whole Building

More than one purpose group on a floor

4.5.1 For multiple *purpose groups* on one floor level, the necessary *fire safety precautions* depend on whether the *purpose groups* occupy the same *firecell* (see Paragraph 4.5.5), or the floor is divided by *fire separations* into different *firecells*.

4.5.2 Where different *purpose groups* are each located in separate *firecells*, each *purpose group* shall adopt the requirements of Table 4.1 which apply to that group. This means a single floor level can have different *fire safety precautions* in each *firecell*.

4.5.3 Where, according to Table 4.1, any *firecell* on a floor level requires a Type 2 alarm, all other *firecells* on that floor shall have no less than a Type 2 alarm.

4.5.4 Where by Table 4.1, any *firecell* on a floor requires a Type 3, 4, 6 or 7 alarm, all other *firecells* on that floor level shall have no less than a Type 3 alarm.

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Table 4.1: Fire Safety Precautions
Key to table references

Part 3	Paragraphs 3.1.5, 3.13.1 and 3.19.2
Part 4	Paragraphs 4.3, 4.3.1, 4.3.3, 4.4.1, 4.5.2, 4.5.3, 4.5.4, 4.5.7, 4.5.8, 4.5.9, 4.5.10, 4.5.13, 4.5.14, 4.5.15, 4.5.19
Part 5	Paragraphs 5.5.1, 5.6.6, 5.6.8, 5.9.4 c)
Part 6	Paragraphs 6.2.1, 6.4.1, 6.7.1, 6.8.1, 6.8.5, 6.8.6, 6.10.1, 6.11.1, 6.15.1, 6.19.9, 6.21.2, 6.23.1 d), 6.23.2, 6.23.3
Part 8	Paragraphs 8.2.1, 8.2.2, 8.2.3
Appendix A	Paragraphs A1.1.1 and A1.1.2

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Fire safety precautions

Type	Description
1	Domestic smoke alarm system.
2	Manual fire alarm system.
3	Automatic fire alarm system with heat detectors and manual call points.
4	Automatic fire alarm system with smoke detectors and manual call points.
5	Automatic fire alarm system with modified smoke/heat detection and manual call points.
6	Automatic fire sprinkler system with manual call points.
7	Automatic fire sprinkler system with smoke detectors and manual call points.
8	Voice communication system.
9	Smoke control in air handling system.
10	Natural smoke venting.
11	Mechanical smoke extract.
12	No Type 12 currently specified.
13	Pressurisation of safe paths.
14	Fire hose reels.
15	Fire Service lift control.
16	Emergency lighting in exitways.
17	Emergency electrical power supply.
18	Fire hydrant system.
19	Refuge areas.
20.	Fire systems centre.

Special applications

a Not required where:
  i) the *escape routes* serve an *occupant load* of no more than 50 in *purpose groups* CS (excluding *early childhood centres*), CM, WL, WM, WH and WF, or
  ii) the *escape routes* are for *purpose group* SA and serve no more than 10 beds, (or 20 beds for trampers huts, see Paragraph 6.20.6), or
  iii) exit doors from *purpose group* SA and SR *firecells* open directly onto a *safe place* or an external *safe path* (see paragraph 3.14).

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b Where only a single *escape route* is available, no less than a Type 4 alarm is required. See Paragraph 3.15.3 for situations where sprinklers are required.

c Required where Fire Service hose run distance, from the Fire Service vehicular access (see Paragraph 8.1.1) to any point on any floor, is greater than 75 m.

d Emergency lighting extended to *open paths* throughout the *firecell*.

e Type 5 is permitted as an alternative alarm system within *firecells* containing sleeping accommodation. (See Appendix A for description of Type 5.)

f A direct connection to the Fire Service is not required provided a telephone is installed and freely available at all times to enable 111 calls to be made.

Note:
The numbered references are more fully explained in Appendix A.
Throughout Table 4.1 dark shading identifies where sprinklers are required.

Table 4.1/1: Fire safety precautions for active purpose group firecells Occupant load 100

Purpose group	FHC	Escape height: 0 m (or single floor)	<4 m (or two floors)		4 m to <10 m		10 m to <25 m		25 m to <34 m	34 m to <46 m	46 m to <58 m	over 58 m
CS	1	F0	F45		F45		F45		F30	F45	F45	F60
	2	F0	F60		F60		F60		F45	F45	F60	F90
	3	F0	F60		F60		F90		F45	F60	F60	F90
		2af 18c	2af 18c		3b 9 16 18c		4 9 16 18		6 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 17 18 19 20
CM	2	F0	F60		F60		F60		F45	F45	F60	F90
(Note 5)	4	F0		F30		F30		F45	F45	F60	F60	F90
		2af 18c	2af 18c	6 18c	3b 9 16 18c	6 9 16 18c	3b 9 15 16 18	6 9 15 16 18	6 9 13 15 16 18	7 9 13 15 16 18 20	7 9 13 15 16 18 20	7 9 13 15 16 17 18 19 20
WL	1	F0	F45		F45		F45		F30	F45	F45	F60
WM	2	F0	F60		F60		F60		F45	F45	F60	F90
WH	3	F0	F60		F60		F90		F45	F60	F60	F90
(Note 5)	4	F0		F30		F30		F45	F45	F60	F60	F90
		2af 18c	2af 18c	6 18c	3b 16 18c	6 16 18c	3b 15 16 18	6 15 16 18	6 15 16 18	6 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
WF	4	F0	F30		F30		F45		F45	F60	F60	F90
		3af 18c	6 18c		6 16 18c		6 15 16 18		6 15 16 18	6 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
Column		1	2		3		4		5	6	7	8

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraph 5.6.11 for concessions for *FHC* 4.

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Table 4.1/2: Fire safety precautions for active purpose group firecells Occupant load 101 to 500

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Purpose group	FHC	Escape height 0 m (or single floor)	<4 m (or two floors)		4 m to <10 m		10 m to <25 m		25 m to <34 m	34 m to <46 m	46 m to <58 m	over 58 m
CL	1	F0	F45		F45		F45		F30	F45	F45	F60
(Notes	2	F0	F60		F60		F60		F45	F45	F60	F90
6,7)	3	F0	F60		F60		F90		F45	F60	F60	F90
		3f 16 18c	3f 16 18c		3b 9 16 18c		4 9 16 18		6 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 17 18 19 20
CM	2	F0	F60		F60		F60		F45	F45	F60	F90
(Note 5)	4	F0		F30		F30		F45	F45	F60	F60	F90
		3f 16 18c	3f 16 18c	6 16 18c	3b 9 16 18c	6 9 16 18c	3b 9 15 16 18	6 9 15 16 18	6 9 13 15 16 18	7 9 13 15 16 18 20	7 9 13 15 16 18 20	7 9 13 15 16 17 18 19 20
WL	1	F0	F45		F45		F45		F30	F45	F45	F60
WM	2	F0	F60		F60		F60		F45	F45	F60	F90
WH	3	F0	F60		F60		F90		F45	F60	F60	F90
(Note 5)	4	F0		F30		F30		F45	F45	F60	F60	F90
		3f 16 18c	3f 16 18c	6 16 18c	3b 16 18c	6 16 18c	3b 15 16 18	6 15 16 18	6 15 16 18	6 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
WF	4	F0	F30		F30		F45		F45	F60	F60	F90
		3f 16 18c	6 16 18c		6 16 18c		6 15 16 18		6 15 16 18	6 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
Column		1	2		3		4		5	6	7	8

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraph 5.6.11 for concessions for *FHC* 4.
6. **CL cinemas and theatres:** Type 16d is required for all *escape heights*.
7. **CL:** For *firecells*, which are not cinemas or *theatres*, with *escape height* less than 4.0 m and *occupant load* not greater than 250, Type 2f is a permitted alternative to Type 3f.

Amend 4 Oct 2005

Amend 5 Oct 2005

Table 4.1/3: Fire safety precautions for active purpose group firecells Occupant load 501 to 1000

Purpose group	FHC	Escape height: 0 m (or single floor)	<4 m (or two floors) (FHC 1–3)	<4 m (or two floors) (FHC 4)	4 m to <10 m (FHC 1–3)	4 m to <10 m (FHC 4)	10 m to <25 m	25 m to <34 m	34 m to <46 m	46 m to <58 m	over 58 m
CL	1	F0	F45		F45		F30	F30	F45	F45	F60
(Note 6)	2	F0	F60		F60		F30	F45	F45	F60	F90
	3	F0	F60		F60		F45	F45	F60	F60	F90
		4 16 18c	4 16 18c		4 9 16 18c		7 9 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 17 18 19 20
CM	2	F0	F60		F60		F30	F45	F45	F60	F90
(Note 5)	4	F0		F30		F30	F45	F45	F60	F60	F90
		4 16 18c	4 16 18c	6 16 18c	4 9 16 18c	6 9 16 18c	7 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 20	7 9 13 15 16 18 20	7 9 13 15 16 17 18 19 20
WL	1	F0	F45		F45		F30	F30	F45	F45	F60
WM	2	F0	F60		F60		F30	F45	F45	F60	F90
WH	3	F0	F60		F60		F45	F45	F60	F60	F90
(Note 5)	4	F0		F30		F30	F45	F45	F60	F60	F90
		4 16 18c	4 16 18c	6 16 18c	4 16 18c	6 16 18c	7 15 16 18	7 15 16 18	7 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
WF	4	F0	F30		F30		F45	F45	F60	F60	F90
		4 16 18c	6 16 18c		6 16 18c		7 15 16 18	7 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
Column		1	2		3		4	5	6	7	8

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* an *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraph 5.6.11 for concessions for *FHC* 4.
6. **CL cinemas and theatres:** Type 16d is required for all *escape heights*.

Amend 4 Oct 2005

Table 4.1/4: Fire safety precautions for active purpose group firecells Occupant load over 1000

Purpose group	FHC	Escape height 0 m (or single floor)	<4 m (or two floors)	4 m to <10 m	10 m to <25 m	25 m to <34 m	34 m to <46 m	46 m to <58 m	over 58 m
CL	1	F0	F30	F30	F30	F30	F45	F45	F60
(Note 6)	2	F0	F30	F30	F30	F45	F60	F60	F90
	3	F0	F30	F30	F45	F45	F60	F60	F90
		7 16d 18c	7 16d 18c	7 9 16d 18c	7 9 16d 18	7 9 13 15 16d 18	7 9 13 15 16d 18	7 9 13 15 16d 18	7 9 13 15 16d 17 18 19 20
CM	2	F0	F30	F30	F30	F45	F45	F60	F90
(Note 5)	4	F0	F30	F30	F45	F45	F60	F60	F90
		7 16d 18c	7 16d 18c	7 9 16d 18c	7 9 15 16d 18	7 9 13 15 16d 18	7 9 13 15 16d 18 20	7 9 13 15 16d 18 20	7 9 13 15 16d 17 18 19 20
WL	1	F0	F30	F30	F30	F30	F45	F45	F60
WM	2	F0	F30	F30	F30	F45	F45	F60	F90
WH	3	F0	F30	F30	F30	F45	F60	F60	F90
(Note 5)	4	F0	F30	F30	F30	F45	F60	F60	F90
		7 16 18c	7 16 18c	7 16 18c	7 15 16 18	7 15 16 18	7 9 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
WF	4	F0	F30	F30	F45	F45	F60	F60	F90
		7 16 18c	7 16 18c	7 16 18c	7 15 16 18	7 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18	7 9 13 15 16 18 19 20
Column		1	2	3	4	5	6	7	8

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to Paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** Refer to Paragraph 5.6.11 for concessions for *FHC* 4.

Amend 4 Oct 2005

Table 4.1/5: Fire safety precautions for sleeping purpose group firecells
Occupant load 40 maximum

Purpose Group	FHC	Escape height 0 m (or single floor)	<4 m (or two floors)	4 m to <10 m	10 m to <25 m	25 m to <34 m	34 m to <46 m	46 m to <58 m	over 58 m
SC SD	1	F0	F30	F30	F30	F30	F45	F45	F60
		7 16d 18c	7 16d 18c	7 16d 18c	7 9 15 16d 18	7 8 9 13 15 16d 18 20	7 8 9 13 15 16d 18 20	7 8 9 13 15 16d 18 20	7 8 9 13 15 16d 17 18 19 20
SA (Note 5)	1	F0	F45	F45	F45	F30	F45	F45	F60
		4aef 16a 18c	4ef 16a 18c	4e 14 16a 18c	4e 14 15 16 18	7e 8 9 15 16 18	7e 8 9 13 15 16 18 20	7e 8 9 13 15 16 18 20	7e 8 9 13 15 16 17 18 20
SR (Note 7)	1	F0	F45	F45	F45	F30	F45	F45	F60
			2a	2f 16a	4e 14 16 18	7e 15 16 18	7e 15 16 18	7e 15 16 18 20	7e 13 15 16 18 20
Column		1	2	3	4	5	6	7	8

Notes:

1. **Use of table:** Refer to Paragraph 4.4 for instructions on using this table to determine the *fire safety precautions* in *firecells*.
2. **Adjoining firecells having a F0 rating:** Paragraph 6.2.1 requires adjoining *firecells* to be separated by *fire separations* with *FRR* no less than 30/30/30.
3. **Intermediate floors:** Where a *firecell* contains *intermediate floors* a *FRR* shall apply to the *intermediate floors* and supporting elements, and smoke control systems Type 9 and either Type 10 or Type 11, are required (see Paragraphs 4.5.16 to 4.5.18, 6.14.3 and 6.21.5 to 6.22.14).
4. **Car parking:** Refer to paragraphs 6.10.3 to 6.10.6 for car parking provisions within *buildings*.
5. **Sprinklers:** *Purpose group* SA may have an *occupant load* up to 160 beds in *firecells* with a Type 7 alarm (see Paragraph 6.7.2).
6. **Occupant load in SC and SD firecells:** The *occupant load* in a *group sleeping area firecell* is limited to 12 or 20 beds and in a *suite* to six beds (see Paragraphs 6.6.3 to 6.6.5). For *firecells* (such as an operating theatre) required to remain occupied during a *fire*, see Paragraphs 5.6.8 and 5.6.9.
7. **SR household units:** See Paragraph 6.8.6 which describes where *household units* containing upper floors may be treated as single floor *firecells*. Amend 4 Oct 2005

B.4 Requirements for surface finishes

Amend 5 Oct 2005

Table 6.2: Requirements for Interior Surface Finishes and Suspended Flexible Fabrics to Inhibit Fire Spread
Paragraphs 6.18.2 d), 6.20.2, 6.20.5, 6.20.7, 6.20.16, 6.20.20 and 6.20.21

Building elements	Purpose group or location (Note 1)	Maximum permitted index SFI	SDI	FI	Row
Walls, ceilings (Note 2)	*Exitways* in all *purpose groups*. Sleeping areas in *purpose groups* SC and SD.	0	3	-	1
	All *occupied spaces* in *purpose groups* CS and CL excluding *exitways* (see also Paragraph 6.20.7). All *occupied spaces* in *purpose group* CM where the *occupant load* is greater than 50. Sleeping areas in *purpose group* SA (see also Paragraph 6.20.6 for trampers' huts).	2	5	-	2
	Passageways, corridors and *stairways* not being part of an *exitway* in all *purpose groups* except SH and SR.	7	5	-	3
	Minimum requirement for all *occupied spaces* in all *purpose groups* except within *household units* in *purpose groups* SR and SH.	5 or 9	10 8	- -	4
	Within individual *household units* in *purpose groups* SR and SH.	Nil requirement			5
Flooring (coverings)	*Exitways*. Any *occupied space* in *purpose groups* SC and SD.	*Non-combustible*, or have low radius of effects of ignition (see Paragraph 6.20.8).			6
Ducts for *HVAC* systems	Internal surfaces.	0	3	-	7
	External surfaces.	7	5	-	8
Acoustic treatment and pipe insulation	Within air-handling plenum in *purpose groups* SC, SD, SA and SR.	7	5	-	9
Suspended flexible fabrics	*Exitways* serving *purpose groups* SC, SD, SA, SR and CO. All *occupied spaces* in *purpose groups* CS and CL including *exitways*. All *occupied spaces* including *exitways* in *purpose group* CM where *occupant load* is greater than 50. Underlay to exterior cladding or roofing when exposed to view in *occupied spaces* in *purpose groups* SC, SD, SA, WL, WM, WH, WF, CO, CM, CS, CL and IE.	-	-	12	10
Membrane structures	*Purpose groups* CM, CS and CL.	Pass the *standard test* for flammability of membrane structures.			11
Column 1	2	3			
Key:	**SFI = spread of flame index** **SDI = smoke developed index** **FI = flammability index**	**(The smaller the index number the more stringent the requirement)**			

Notes:

1. For the purposes of this table, the term *"occupied spaces"* means a space that can be expected to be occupied during normal use of the *building* by its intended occupants. It does not include *concealed spaces* or ceiling cavities which may be accessed only through a hatch, or plant rooms and the like occupied only for maintenance purposes.
2. **Sprinklered firecells:** see Paragraph 6.20.5 for reduced requirements in sprinklered *firecells*.

B.5 Fire safety precautions

Appendix A: Fire Safety Precautions

A1.1 Types of FSP

A1.1.1 The Key to Table 4.1 lists different Types of *fire safety precautions*. Types 2 to 7 are alarm systems and the others are specific provisions aimed at facilitating safe evacuation, rescue and *fire* fighting activity.

A1.1.2 Depending on the *fire hazard*, one or more *FSPs* are required, by Table 4.1, to be applied to the *firecell* being considered.

A1.2 Fire Alarm and Sprinkler Systems

A1.2.1 *Fire* alarm systems used in *fire safety precautions* Types 2 to 7 shall satisfy all the requirements of F7/AS1. *Fire* sprinkler systems used in the *fire safety precautions* Types 6 and 7 shall also satisfy all the requirements of Appendix D.

A1.3 Requirements Common to Alarm System Types 2 to 7

Amend 2 Apr 2003

A1.3.1 Except for Type 1 Systems, each *fire* alarm system, regardless of method of activation, shall be provided with a means of communication with the Fire Service in accordance with F7/AS1 Paragraph 2.2.

A2.1 FSP Descriptions

A2.1.1 The following text provides a brief description of each *FSP*. More detailed information is supplied in F7/AS1 for Types 2 to 7.

Type 1 Domestic Smoke Alarm System

A stand-alone domestic/residential type automatic smoke detection and alarm system with limited coverage that activates automatically in the presence of smoke. This system **may** be battery powered and has detectors and alerting devices. The system is restricted to a single *firecell* and does not have a connection to the Fire Service or an indicating unit.

Amend 2 Apr 2003

COMMENT:

This system is for use only within *household units*, and is intended to provide early warning to the occupants.

Amend 2 Apr 2003

Type 2 Manual fire alarm system

An alarm system which is activated only by someone operating a manual call point. It is a single or multiple zone system with an alarm panel providing a zone index diagram and defect warning, and suitable for connection to the Fire Service.

Type 3 Automatic fire alarm system activated by heat detectors and manual call points

A detection and *fire* alarm system, which activates automatically when a pre-determined temperature is exceeded in the space, and can be activated manually at any time.

Type 4 Automatic fire alarm system activated by smoke detectors and manual call points

A detection and *fire* alarm system which activates automatically in the presence of smoke, and can be activated manually at any time. Type 5 is an optional alternative to this system for *purpose groups* SA and SR.

COMMENT:

Smoke detectors should not be located in spaces where the activity within that space (e.g. a kitchen or smokers bar) is likely to initiate a false alarm. See F7/AS1 for alternative systems.

Type 5 Automatic fire alarm system with modified smoke detection and manual call points

A variation of the Type 4 and Type 7 alarm systems permitting part of the smoke detection component to comprise only a local alarm.

The local alarm system, activated by the presence of smoke, has audible alerting devices to warn only the *firecell* occupants and the *building* management, where such management exists. Examples of such management situations are motels, hotels or multi-unit residential accommodation in a retirement village.

The local alarm component of a Type 5 system:

a) Is restricted to single *firecells* containing sleeping accommodation being *household units* in *purpose group* SR or individual *suites* in *purpose group* in SA. The local alarm system shall not be extended to other areas such as *exitways* or common spaces which shall retain a Type 4 smoke detection system, and

b) Shall be permitted only where an automatic *fire* detection and alarm system activated by heat detectors (part of the main alarm system) is also installed in sleeping *firecells* which do not already have an automatic sprinkler system.

COMMENT:

The local smoke alarm provides the necessary early *fire* warning for the *firecell* occupants. If the *firecell* is unoccupied or if the occupants fail to respond to the local alarm and there is a developing *fire*, the automatic alarm activated by either heat detectors or sprinklers will alert the Fire Service and occupants in the *building*.

The small increase in risk, due to the brief delay between activation of the local smoke alarm and activation of the automatic alarm, is more than compensated for by avoiding Fire Service call out and total *building* evacuation in the event of a false alarm in one *firecell*.

Type 6 Automatic fire sprinkler system with manual call points

An automatic *fire* detection, alarm and control system which, when a specified temperature is exceeded in the space, activates the sprinkler head in the affected area and includes alerting devices throughout the *building*. The system permits alerting devices to be activated manually.

Type 7 Automatic fire sprinkler system with smoke detectors and manual call points

An automatic *fire* alarm system having the same characteristics as a Type 6 alarm plus an automatic smoke detection system. The *fire* alarm signal resulting from smoke detection need not be directly transmitted to the Fire Service.

A Type 5 alarm is an optional alternative in SA or SR *purpose groups* for part of the smoke detection component of the Type 7 system. (Refer to Type 5 above for specific requirements.)

COMMENT:

Smoke detectors are used to gain an earlier warning to life threatening situations than may be achieved from the response of sprinklers, particularly where a smouldering *fire* does not produce enough heat in its early stages to activate a sprinkler head.

Type 8 Voice communication system

An automatic system with variable tone alerting devices, the facility to deliver voice messages to occupants, and to allow two-way communication between emergency services personnel.

Voice communication systems shall comply with AS 2220: Parts 1 and 2.

COMMENT:

A voice communication system, particularly in tall *buildings*, permits controlled evacuation. In cases where the sprinkler system and Fire Service achieve early control of the *fire*, it may be necessary to evacuate only part of the *building*.

Type 9 Smoke control in air-handling system

Heating, ventilating or airconditioning systems if installed in *buildings*, shall comply with the requirements for smoke control in Part 6.

These shall be installed with either:

a) Self contained detection, control and provision of output signal/alarm generally to comply with AS/NZS 1668: Part 1 and interface with any Type 3, 4, or 7 system installed, or

b) *Fire* alarm and warning systems Type 3, 4 or 7 as a means of smoke detection, in accordance with NZS 4512 to provide ancillary function output for control of the *HVAC* system.

Type 10 Natural smoke venting

This is a method of smoke extraction where a *firecell* is provided with a smoke reservoir, and with outlet vents and fresh air inlets which open automatically when actuated by the smoke detection system. Smoke movement is by natural draught.

Type 10 requirements apply only to the common space (such as an atrium) in *firecells* with *intermediate floors*.

COMMENT:

These systems are used in *firecells* with *intermediate floors* and having an *occupant load* which is not great enough to justify a mechanical extraction system. Requirements for smoke reservoirs and natural smoke ventilation systems are given in Paragraphs 6.22.8 to 6.22.10.

Type 11 Mechanical smoke extract

Mechanical smoke extract uses fans in place of the natural draught relied upon in Type 10. The *firecell* shall have smoke reservoirs. The system shall comply with the requirements of Paragraphs 6.22.8 c), 6.22.9 and 6.22.11 to 6.22.14. Type 11 requirements apply only to the common space in *firecells* with *intermediate floors*.

Type 12 Deleted

Type 13 Pressurisation of safe paths

Pressurisation methods and installation shall comply with AS/NZS 1668: Part 1 Section 9. The system shall be automatically activated by smoke detectors, and shall keep the *safe paths* free of smoke for sufficient time to allow occupants to reach a safe place, and in no case for less than 60 minutes.

COMMENT:

1. AS/NZS 1668 gives airflow speed and pressure requirements which ensure effective pressurisation without causing occupants to have difficulty opening doors.
2. Pressurisation is generally necessary only for vertical *exitways* where the *escape height* exceeds 25 m.

Type 14 Fire hose reels

Fire hose reels shall comply with AS/NZS 1221, and the distribution, installation and maintenance with NZS 4503, except that the maximum hose length shall be 36 m. *Fire* hose reels shall not be installed in vertical safe paths.

COMMENT:

Fire hose reels are required primarily for use by the New Zealand Fire Service and also for situations where they may be operated by people experienced in their use.

Type 15 Fire Service lift control

The Fire Service lift control where required, shall enable the Fire Service to have exclusive use of any lift for *fire* fighting purposes. Once a Type 15 *FSP* is required for any level in a *building*, it shall be applied to all levels.

COMMENT:

A first priority of the Fire Service is to assist with the evacuation of non-ambulant occupants, and to locate any occupants who may be trapped. In multi-floor *buildings*, lifts can greatly reduce the time taken to accomplish these tasks.

Type 16 Emergency lighting in exitways

Emergency lighting shall comply with F6/AS1. Such lighting is required where occupants (particularly crowd and sleeping *purpose groups*) would find it difficult to reach a *safe place* because of a main power supply failure. Emergency lighting requirements for *purpose group* CO (which is not included in Table 4.1) shall be as for *purpose groups* CS and CL. Emergency lighting is not required in infrequently inhabited spaces such as plant rooms, storage areas and service tunnels of *purpose groups* IA and ID.

When required by Table 4.1, the minimum provision is for emergency lighting to be installed in all *exitways*. However emergency lighting may be required in other spaces within a *firecell*. Table 4.1 for each *purpose group* nominates where, in addition to the *exitways*, emergency lighting shall be extended to the *open path*.

Type 17 Emergency electrical power supply

The emergency power supply is necessary to ensure the continued operation during evacuation, of essential equipment such as smoke control systems, emergency lighting and lifts. Detailed requirements are given in Paragraph 6.23.3. The requirement applies generally to tall *buildings* having sleeping accommodation or crowds (see Table 4.1 for specific situations).

Type 18 Fire hydrant system

Fire hydrant systems shall comply with NZS 4510 "Fire hydrant systems for buildings". Once a Type 18 *FSP* is required for any level in a *building*, it shall be applied to all levels.

Type 19 Refuge areas

Refuge areas are required within *safe paths* in tall *buildings* where congestion is likely to occur. They also provide an opportunity for slow moving occupants to rest without constricting the movement of others. The locations and sizes of refuge areas are given in Paragraph 3.13.

Type 20 Fire systems centre

A facility for Fire Service use which shall:

a) Be readily accessed from street level and located in a position to be determined in consultation with the New Zealand Fire Service,

b) Be protected from the effects of *fire* including debris falling from an upper floor, and

c) Contain all control panels indicating the status of *fire* safety systems installed in the *building*, together with all control switches.

Appendix C NZFS REQUIREMENTS FOR EVACUATION SCHEMES

Evacuation schemes are required under the Fire Service Act 1975 No 42, 21B(2).

The New Zealand Fire Service requirements that deem a building must have an evacuation scheme are accessible at http://evaconline.fire.org.nz/ and are stated as follows.

A building requires an evacuation scheme that has been approved by the Fire Service if it is a relevant building.

A *relevant building* is a building that is used for one or more of the following purposes:

- the gathering together, for any purpose, of 100 or more persons
- providing employment facilities for 10 or more persons
- providing accommodation for more than five persons (other than three or fewer *household units*)
- storing or processing *hazardous substances* in quantities exceeding the prescribed minimum amounts – see Appendix B of the Guide (NZFS 2010) for a list of these amounts
- providing early childhood facilities (other than in a *household unit*)
- providing nursing, medical, or geriatric care (other than in a *household unit*)
- providing specialised care for people with disabilities (other than in a *household unit*)
- providing accommodation for persons under lawful detention (other than home detention, community detention or parole).

EXCEPT

If the *building* is only a relevant building because it is used for **one** of:

- providing employment facilities for 10 or more persons
- providing accommodation for more than five persons (other than three or fewer *household units*)

and it has an *automatic sprinkler system* (as described in Regulation 16), the *building owner* is not required to provide and maintain an *evacuation scheme* for the building.

However, the building owner must notify the Fire Service that an evacuation scheme is not required, using the form in Schedule 4 of the Regulations. The NZFS version of the form (called a section 21B(2) notice) is available from the left-hand menu on the website above..

Sample of sign from NZFS requirements

Appendix E – Fire sign example

Fire signs are available in other languages from the fire information unit (refer to Appendix F).

FIRE ACTION

IF YOU DISCOVER A FIRE:

WARN OTHER BUILDING OCCUPANTS
OPERATE FIRE ALARM & PHONE THE FIRE SERVICE

DIAL 111

(FROM A SAFE PHONE)

WHEN WARNED OF A FIRE IN THIS BUILDING:

LEAVE THE BUILDING IMMEDIATELY USING THE NEAREST EXIT WHICH IS:

YOUR ALTERNATIVE EXIT IS AT:

ASSEMBLE AT:

WALK - DO NOT RUN

STAY AT THE ASSEMBLY POINT UNTIL THE "ALL CLEAR" IS GIVEN.

DO NOT ATTEMPT TO EXTINGUISH THE FIRE UNLESS IT IS SAFE TO DO SO.

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Appendix D VERO CENTRE

From Wikipedia, the free encyclopedia
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Vero Centre

The building from the north.

General information	
Location	Shortland Street, Auckland City
Status	Complete
Constructed	2000
Use	Office tower
Height	
Roof	167.5 m (549.5 ft)

Technical details	
Floor count	38
Floor area	68,900 m^2 (741,630 sq ft) gross 39,450 m^2 (425,000 sq ft) lettable 4,250 m^2 (46,000 sq ft) site area
Elevators	12
Companies involved	
Architect(s)	PTW Architects
Developer	Kiwi Income Property Trust
Owner	Kiwi Income Property Trust
References: [1]	

The **Vero Centre** (constructed as the **Royal & SunAlliance Centre**)[1] is a high rise office tower located in Auckland, New Zealand. Constructed in 2000, it was Auckland's first major tower built since the 1980s. The centre contains a health club and gymnasium, main entry public foyer, retail outlets in the 5 podium levels and 32 office levels. As of 2005, it is New Zealand's tallest "and most technologically advanced" landmark office tower. It is also known for its "halo" roof feature.[1]

While atypically high compared to the surrounding area, its construction is considered to have had a positive effect on the regeneration of the eastern Auckland CBD area.[1]

The site had previously been occupied by a number of vancant lots and low-rise buildings, including student accommodation, industrial warehouses and massage parlours. The developer's design process for the new site made use of the "bonus provisions" of the District Plan, allowing them to build more floor area in exchange for public benefits like displayed works of art and a public plaza. The value of these to the general public has however been called into question by some. Also criticised has been the lack of connection between the two frontage streets through the building.[1]

The building received several awards for energy efficiency (such as the RICS International Award for Building Efficiency and Regeneration in 2001 and the EnergyWise Award 2004), and has been calculated to use around 10% less energy than the average New Zealand Property Council building.[1]