Fire Research Report

Fire Design for Aging Residential Occupancies

BRANZ

October 2011

The current situation is that older adults (65+) represent 12% of our community. This is predicted to increase to approximately 25% in 30 years. Older adults are a vulnerable part of our community with high fire risk resulting in a disproportionate representation in fire casualties. Older adults fall into the lower percentiles of the parameters describing emergency egress of the general population such as mobility, sensory deprivation, cognitive response etc, therefore reducing the likelihood of successful escape. Therefore guidance on the differences between design for residential buildings intended for the primary use of older people compared to a „general population" occupancy is needed immediately. The main focus of this report is discussion of what differences there would be in residential fire safety design to account buildings that are targeted to older segments of our community compared to general residential buildings, where there is a wider distribution of ages of the intended occupancy.

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Fire Design for Aging Residential Occupancies

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Preface

This report was prepared during research into fire safety design associated with residential occupancies that are predominately older adults.

Acknowledgments

This work was jointly funded by the Building Research Levy and the New Zealand Fire Service Commission Contestable Research Fund.

Note

This report is intended for regulators, researchers and fire safety engineers.

Executive Summary

It has previously been commented that older adults (65+ years) fall into the lower percentiles of the metrics associated with emergency egress of the general population (i.e. 0 to 85+ years) (USFA 2006; Kuligowski 2009; Chalmers 2000; Roen and Lloyd 2002; Aherns 2003). This is leads to a reduced likelihood for successful escape that is realised in the disproportionate representation in fire casualties (e.g. 30% of total residential fire fatalities in NZ (Challands 2009), which is consistent with US casualty statistics (USFA 2001; Aherns 2003)). However residential design that is intended to target segments of our community, such as older adults, uses design parameter values based on the general population.

The older adult segment of our community currently represents 12% of the New Zealand population. This is predicted to increase to approximately 25% in 30 years (University of Waikato 2009). This, combined with the growing tendency for individuals to remain longer in their own home (Dalziel 2001), may make a marked impact on the characteristics of the 'general residential population' as well as making targeted residential buildings more likely.

Therefore guidance on the differences between design for residential buildings intended for the primary use of older people compared to a 'general population' occupancy is needed immediately.

The main focus of this report is discussion of what differences there would be in residential fire safety design to account buildings that are targeted to older segments of our community compared to general residential buildings, where there is a wider distribution of ages of the intended occupancy.

The approach taken as part of this study was to collate available literature and data for the metrics that can be used to describe occupants related to emergency egress, so that, if possible, the characteristics of the general population could be compared to older people. The metrics of interest here are related to mobility, sensory response, cognitive response, etc. However there is little directly relevant published data available.

In terms of the relevant occupant metrics, age alone does not provide a direct measure of capability in terms of successful self-evacuation of a building. There are many aspects of an individual's ability to identify an incident, respond with a self-evacuation plan and execute a plan or gain assistance to escape.

There is age-related degeneration of function and capabilities, which is not well quantified. In addition, just like the 'general population', older adults include people with long-term and temporary disabilities. Therefore the emergency egress capabilities of our older adult population can be influenced by both aged-related and disability-related changes in functionality and limitations.

There is more detail available for disability-related emergency egress limitations than age-related limitations in the published literature. A summary of relevant literature associated with disabilities of older adults, as well as for younger age groups for comparison purposes where useful, forms part of this report. However it is important to keep in mind that disability surveys typically request that the individual compare their capabilities and limitations with those expected of an 'able-bodied peer'. Therefore age-related changes in capabilities and limitations are mostly removed from considerations as well as temporary disabilities (such as pregnancy, short-term illness, medications or injuries, etc.).

Age-related changes in functionality of 'able-bodied' individuals as well as a broad spectrum of attributes and levels of ability of people with long-term and temporary disabilities make up the distributions of metrics for 'general population' occupancies as well as occupancies comprised primarily of older adults, or any other segment of our communities. Therefore, considering the capabilities of a building occupancy to successfully escape, the distributions of occupant metrics are comprised of a combination of:

- ‘able-bodied’,
- age-related,
- long-term disability-related and
- temporary disability-related influences.

It is recommended for the user to be mindful that data sets collected from various surveys (e.g. for healthcare, disability access, assisted care programs, etc.) must be considered in context of the initial intent of the questionnaire and how this influences the applicability when characterising a building occupancy during an emergency fire event.

Metrics that would be of use when assessing an intended building occupancy for emergency egress during a fire may include:

- Physical functionality:
  - Mobility, e.g. movement on horizontal or inclined plains or stairs
  - Agility, e.g. getting in and out of bed or a chair
  - Dexterity, e.g. using door knobs, etc.
- Sensory functionality:
  - Sight
  - Hearing
  - Touch
  - Smell
- Cognitive functionality:
  - Concentration
  - Comprehension
  - Memory
  - Ability to learn

One current approach of incorporating ranges of occupancy capabilities and limitations beyond the generic ‘able-bodied general population’ into building design is ‘accessibility’ for ‘people with disabilities’. However there are two limitations to the current application of this design concept:

- Occupancy capabilities are usually based on a selection of types of long-term disabilities, with a narrow consideration of the higher percentiles of metric ranges, and
- Design of buildings to facilitate access for people with disabilities during normal activities is fundamentally different to design of accessible emergency escape.

Currently, in New Zealand, when considering prescriptive design solutions, the inclusion of accessibility for normal activities is common design practice (e.g. it is included in prescriptive solutions such as D1/AS1 (DBH 2001)), whereby ensuring people with disabilities have safe access into and out of a building during non-emergency situations, where required. Whereas the accessible emergency escape routes are not typically included in prescriptive solutions (e.g. an escape route is only required to be accessible if it happens to coincide with an accessible route according to C/AS1 (DBH 2010)). Therefore people with disabilities may gain access to a building via an accessible route but may have to use a non-accessible escape route during an emergency evacuation. That is, an accessible route is not an accessible escape route. Similarly, an escape route is not an accessible escape route.

In a broader context, emergency egress must be designed for the capabilities and limitations of the intended occupancy, where the ranges of capabilities and limitations are distributions including age-related, temporary disability- and long-term disability-related influences.

For performance-based design approaches, a worked example of a draft for a common framework (Robbins, Gwynne and Kuligowski, 2011) to be used in the selection of fire-safety scenarios for the assessment of specific building designs is included and discussed in the report in terms of potential application to residential buildings with intended older adult occupancies. This proposed framework and worked example was produced in reaction to discussions at the ISO/TC92/SC4/WG11 meeting in Christchurch 2010 of the proposed draft of ISO/WD 29761 Fire safety engineering – Selection of design occupant behavioural scenarios and design behaviours.

Based on the results of this research and the experience gained during this study, recommendations for future research directions include:

- Collection and collation of age-related functionality related to self-rescue and emergency egress from buildings.
    - Collate data and fill voids to create usable distributions of metrics that can be used in design analysis for:
        - General population occupancy (with full age and disability contributions), and
        - Older adult occupancy (65+ years).
    - Include a sensitivity analysis related to changes in distribution of age.
    - Integrate an age-related component to existing quantitative surveys in complementary fields, such as healthcare and disability.
- Development of guidance for best practice for ‘accessible escape route’ design.
    - For buildings that currently require accessible routes, include requirements for accessible escape routes.
- Investigation of the possible approaches to fire safety design to identify the best ways to analyse designs with:
    - intended occupancies are that are well described and characterised to ensure that the range of capabilities and limitations are included
    - identify potential conflicts between building feature requirements for different types of disability
    - assist finding design solutions that accommodate a range of capabilities and limitations including people with and without disabilities.

Fire Design for Aging Residential Occupancies

BRANZ Study Report No. 245

A. P. Robbins

Reference

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Abstract

Older adults (65+ years) represent 12% of our community. This is predicted to increase to approximately 25% in 30 years. Older adults are a vulnerable part of our community with high fire risk resulting in a disproportionate representation in fire casualties.

Older adults fall into the lower percentiles of the parameters describing emergency egress of the general population, such as mobility, sensory response, cognitive response, etc., therefore reducing the likelihood of successful escape. However residential design that is intended for the sole use of older adults uses parameter values based on the general population.

Age alone does not provide a direct measure of capability in terms of successful self-evacuation of a building. There are many aspects of an individual's ability to identify an incident, respond with a self-evacuation plan and execute a plan or gain assistance to escape. Capabilities and limitations of the occupancy relate to both age and other influencing factors such as levels of disability due to accident, illness, etc. whether long-term or temporary.

Metrics of use when characterising an intended building occupancy for emergency evacuation during a fire must cover the three major areas of functionality: physical, sensory and cognitive functionality. Data sets considered from various surveys (e.g. for healthcare, disability access, assisted care programs, etc.) must be interpreted in relation to the context of the initial collection intent and how that influences the range of results in terms of the applicability of use characterising intended building occupants during an emergency event.

Design of buildings to facilitate access for people with disabilities during normal activities is fundamentally different to design of accessible emergency escape. That is, an accessible route is not an accessible escape route. Similarly, an escape route is not an accessible escape route. Fire safety design must be specifically tailored to the fire safety design objective for the intended functionality of the building and usage by the intended occupancy.

A draft for a common framework, for various fire-safety related analysis of performance-based building design approaches, to be used in the selection of fire-safety scenarios for the assessment specific designs are included and discussed in terms of potential application to residential buildings with intended older adult occupancies.

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1. INTRODUCTION

The current situation is that older adults (65+ years) represent 12% of our community. This is predicted to increase to approximately 25% in 30 years (University of Waikato 2009). Older adults are a vulnerable part of our community (Kose 1999; Chalmers 2000; Roen and Lloyd 2002; Aherns 2003; Holborn, Nolan and Golt 2003; Chien and Wu 2008), with high fire risk resulting in a disproportionate representation in fire casualties (e.g. 30% of total residential fire fatalities in NZ (Challands 2009), which is consistent with US (Aherns 2003) and English (Holborn, Nolan and Golt 2003; Mulvaney et al. 2008; Corcoran, Higgs and Higginson 2010) casualty statistics).

Older adults fall into the lower percentiles of the parameters describing emergency egress of the general population (USFA 2006; Kuligowski 2009), such as mobility, sensory response, cognitive response, etc., therefore reducing the likelihood of successful escape. However residential design that is intended for the sole use of older adults uses parameter values based on the general population.

Aged care facilities may include a 'residential wing' where the occupants are considered mostly autonomous before needing to be moved to one of the 'care wings', also 'retirement villages' may offer 'temporary' care or other types of help and therefore are not classed as a 'care' facility. These types of pre-full-time-care facilities fall into the 'residential' type of occupancies, but the current Compliance Document, C/AS1 (DBH 2010), does not provide guidance specific to solely-older-adult residential occupancies. Therefore general residential guidance is typically used instead.

Using general-population residential design parameters may lead to under-designing the fire safety of the building or over-estimating the capabilities of the occupants to evacuate during an emergency. For example, designs have been sighted where the designer has stated that the intended occupants are not as physically capable as in a general residential (e.g. SR) purpose group and used this to remove or reduce aspects of the building fire design to match the reduced occupant capability (e.g. removal of smoke seals and door closers where frail occupants may lack the strength to overcome the forces they impart, and thus removing smoke and fire separation within the building), but still based the remainder of the design on the general residential (e.g. SR) purpose group. This cherry-picking design approach is not appropriate. When the intended building use falls outside of the Compliance Document (as was identified by the designer themselves in the example above), then an alternative solution approach must be applied holistically.

Guidance on the appropriate design for buildings intended for the primary use of older adults is needed immediately.

This project investigated, collected and reviewed available information and data relating to the fire hazards and appropriate design for buildings intended for occupancies of older people.

1.1 Aim of Project

The overall aim of the project was to identify the design characteristics of older adults and the impact on residential fire safety design for solely older adult occupancies as well as the scenario of 'aging in place' (i.e. so people can grow old in their own home without having to move for as long as possible).

The specific objectives of this project were to:

1. Identify the important metrics and associated values for older adults for use in fire safety design.
2. Compare these available quantitative or qualitative values with those used for the broad cross-section of the population for residential occupancies to provide an indication of the magnitude of the problem.
3. Develop initial guidance and recommendations for future residential design where the intended occupancy is exclusively older adults.
4. Develop initial guidance and recommendations for future residential design intended for 'aging in place'.

1.1.1 Objectives of this Report

The objective of this report is to provide a summary of the results of this research and recommendations for guidelines for metrics to be used in compliance documents, alternative solutions and performance criteria for evaluation of designs.

1.1.2 Scope of this Report

This report is a summary of a review of available literature, with implications from different aspects and fields of research or interest discussed and areas that require more information and research highlighted.

The scope of this report is characteristics of sample populations that relate to older people in residential occupancies. Sample populations that include persons with a range of capabilities are included for comparative purposes, where data directly related to older adults in residential buildings is lacking or minimal.

Care facilities are outside the scope of this report. Where references to healthcare or institutional facilities are used, it is only to provide a brief comparative for residential occupancies, especially where there is a current lack of information or directly relevant data.

1.2 Motivation

Older people are acknowledged nationally (Chalmers 2000; Roen and Lloyd 2003) and internationally (Aherns 2003) as a vulnerable group in terms of fire risk. In addition, other fire risk factors such as male gender, non-white ethnicity, low income, disability, smoking and alcohol use (Roen and Lloyd 2003; Diekman et al. 2008) can also apply to older people (Aherns 2003), combining to form an overall higher fire risk profile. As a segment of our population, older people currently represent approximately 12% of our total population, based on 2006 NZ census statistics (University of Waikato 2009). Baby boomers started to turn 65 in 2010. The proportion of our population over 65 is expected to double over the next 30 to 40 years to approximately 25% of the population (University of Waikato 2009). Therefore it is important to identify potential aging-population related fire safety design problems and develop proactive solutions to protect this vulnerable and growing part of our community.

Fire design of buildings intended for the sole use of older people (e.g. retirement villages, aged care facilities, etc.) are currently based on Building Code Compliance

Document purpose groups SH, SR, SA for independent living SC for full-time assisted living and SD for detained care such as for Alzheimer's wards (DBH 2010) and various combinations of these. Purpose groups are typically applied to buildings assuming an occupancy that reflects the average population. In the cases of SH, SR and SA, older people are expected in these occupancies but are assumed to be proportional to the whole population (i.e. currently approximately 12%), and it would be expected that more alert, more mobile occupants would assist others during escape. The impact of the characteristics of older people on fire hazards and risks needs to be identified in order to assess appropriate metrics and assumptions for use in fire safety design.

An example of the concern in this area is where fire design reports have been sighted by the author for buildings intended for the sole use of older people that have been designed based a purpose group of permanent residential (SR). To substantiate the residential-type occupancy the designer cited that the intended occupants can care and cook for themselves and onsite help is only available on request and is considered temporary for each individual. Therefore the building design is based on escape speeds and distances, etc. appropriate for a residential occupancy (specifically purpose group SR). However the intended occupants are then described at the end of the report as not capable of operating doors fitted with closers (required for the residential, SR, fire design) as a reason for the removal of door closers from the building design. Therefore fire and smoke separation is reduced or removed within the building where the baseline design assumed an average cross-section of the population (SR) but in this case the intended occupants are older people, who have a higher fire risk than the average of the cross-section of the population. This situation can be summarised as lower building fire safety protection for a segment of our community that has a higher fire risk.

Guidance on the appropriate design for buildings intended for the primary use of older people would address these types of examples of mismatched intended occupancy and fire safety design.

A previous USFA project (USFA 2006) qualitatively summarised the fire risk factors associated with the older adult for use in identifying education strategies to reduce and prevent fire in older adults' homes and care facilities. A project conducted by NIST (Kuligowski 2009) also included age related qualities influencing behaviour in fire. This work will provide a general basis from which to develop the research proposed here in the direction of metrics for building fire safety design. The proposed project will also utilise the work and design philosophy developed and promoted by other organisations, such as CRESA and Lifetime Design (2010), in terms of designing buildings and communities that includes taking into account our older adults and designing for 'aging in place'. The proposed work also aligns well with the current efforts of ISO TC92/WG11 towards the development of guidance for occupant behavioural scenarios.

1.3 Methodology

The project methodology involved:

- A literature review carried out to summarise and collate previous work that is relevant;
- Identification of the characteristic metrics for aging populations and methods used to describe specific groups within this segment of the population;

- Identification of fire hazards related to the characteristic metrics identified for older people;
- Comparison of characteristics for aging populations with those for other types of occupancies that consider residential or levels of disability (e.g. SH, SR, SA, SC and SD), where the occupancy is assumed to be representative of a cross-section of the whole population;
- Identification of important occupant metrics that need to be considered for building fire safety performance;
- Development of guidelines for description of occupancies of older people and building fire safety design/performance parameters;
- Testing and developing the recommended guidelines based on the results of worked examples (Included as Appendix A, and based on the general approach proposed by Robbins, Gwynne and Kuligowski (2011));
- Summarising and reporting the key findings.

The results of this project are summarised in this report.

2. CHARACTERISTICS OF BUILDING OCCUPANTS

Characterising the intended building occupants is an important aspect of building design (Kobes et al. 2010), especially in terms of assessing the appropriateness of a design for its intended usage and functionality.

Building type, situation and segments of our community are recognised to have statistically different characteristics to the general population. (NFPA 2008; SFPE 2008; Yeo and He 2009) Therefore the general residential population is first considered and then characteristics of the older adult residential segment of our community are discussed.

Although age is not a sole indicator of fire risk or ability to self-rescue, age is a commonly reported metric regarding fire casualties (e.g. Chalmers (2000) Aherns (2003), Roen and Lloyd (2003), Aherns (2007), Graesser, Ball and Bruck 2009; OOFM (2010), etc.). Similarly, age is a commonly used metric for other fields that may also collect or use other metrics that may be related to an ability to self-rescue. Therefore age is the first metric discussed here. Age is considered in terms of the general population and the older segment of the population that reside in residential dwellings.

2.1 General Residential Population based on Age

The general population of New Zealand represents an estimate of the residential occupancy. An estimate of a snap shot of the New Zealand population is presented here, based on available statistical information.

Age is the easiest and most common metric used to classify a population. Therefore age is used as the dominant metric throughout this discussion. The distribution of the New Zealand population based on census data (SNZ 2009) is shown in Figure 1. Estimates of the future distribution of the New Zealand population have been published by Statistics New Zealand using previous census data sets. The average estimates for the future distribution of the population are shown in Figure 2 and, using broader ranges for the age groups, Figure 3. The median age group and 95th and 97th percentiles are summarised in Table 1 for the census data and average future estimates. The median age group has been steadily rising from 30 to 34 years in 1996 to 35 to 39 years in 2006. Similarly the 95th and 97th percentiles have also been increasing, with the 80 to 85 year age group for both the 95th and 97th percentiles in 2006. Predictions of future population changes by Statistics New Zealand (SNZ 2009) indicate that these increases are expected to continue.

In light of the distribution and changes in distribution of the age of the New Zealand population between censuses and expected into the future, the use of estimates of metric values to describe characteristics of an intended occupancy based on a distribution or a single value need to be acknowledged in good design analysis. When using single values to characterise a residential occupancy, just like any other type of building occupancy, it is important to know what the values represent and therefore how to appropriately interpret analysis results. For example, whether the mean, median, 95th percentile, 97th percentile or some other measure is used, the results will be related to a small portion of the occupancy, conservative for another part of the occupancy and an overestimate of the reasonably expected capabilities of the remainder of the occupancy.

Table 1: Summary of statistics on age of the general New Zealand population based on census results (SNZ 2009)

	Age Group			
	1996 Census	2001 Census	2006 Census	Average Estimate for 2061
Median	30-34	30-34	35-39	40-44
95th Percentile	70-74	75-79	80-85	85-89
97th Percentile	75-79	75-59	80-85	85-89
Range	0 to 90+	0 to 90+	0 to 90+	0 to 90+

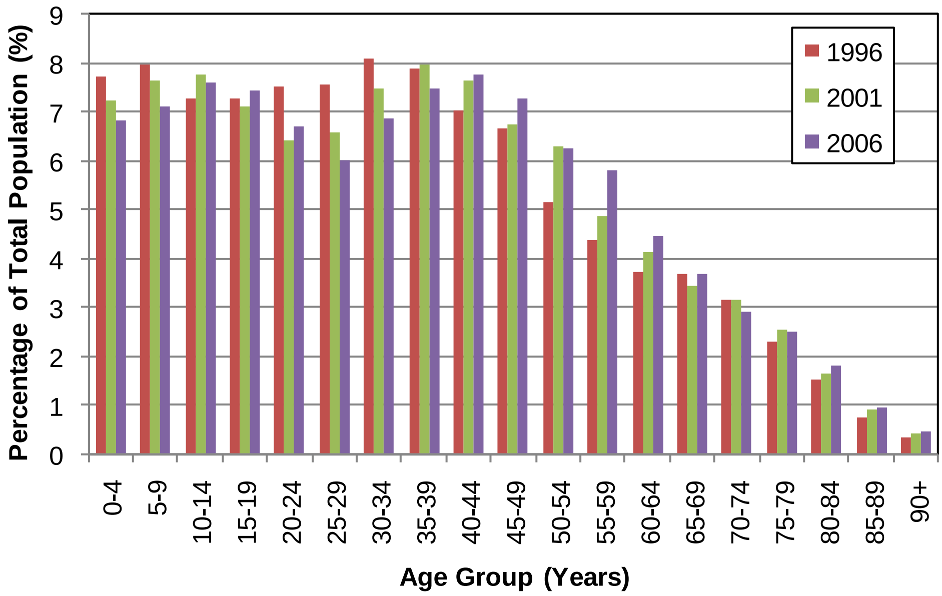

Figure 1: Age distribution of the New Zealand population as reported for 1996, 2001 and 2006 census data (SNZ 2009).

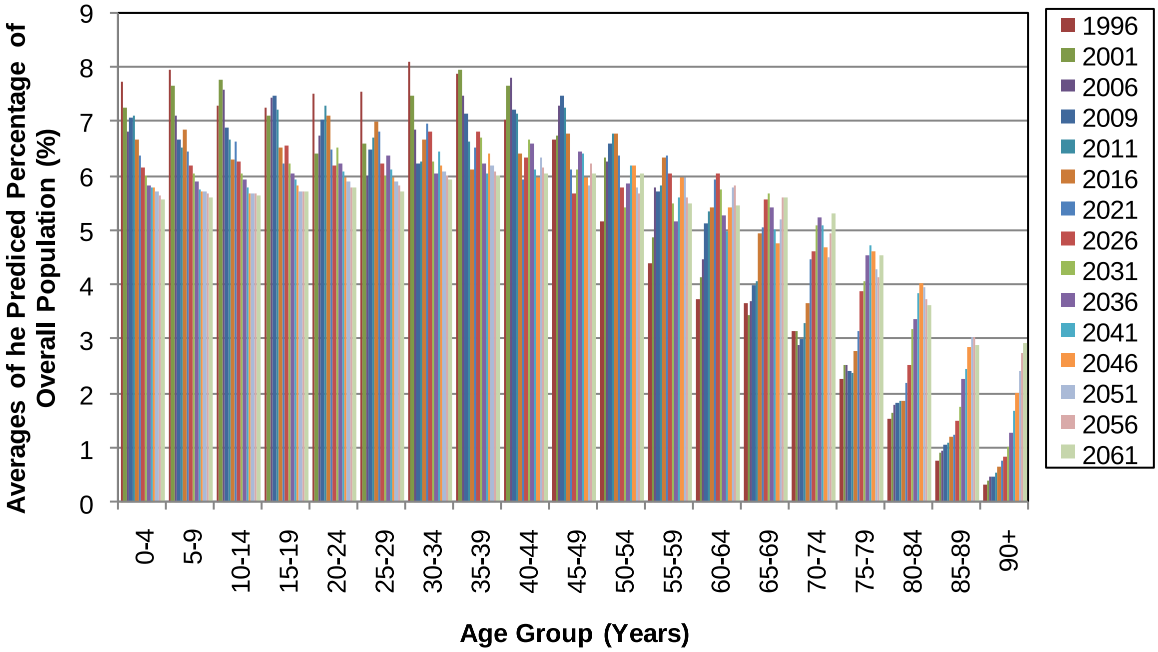

Figure 2: Averages of the predicted estimates for the age distribution of the New Zealand population (2011 to 2061) estimated from 2006 census data (SNZ 2009).

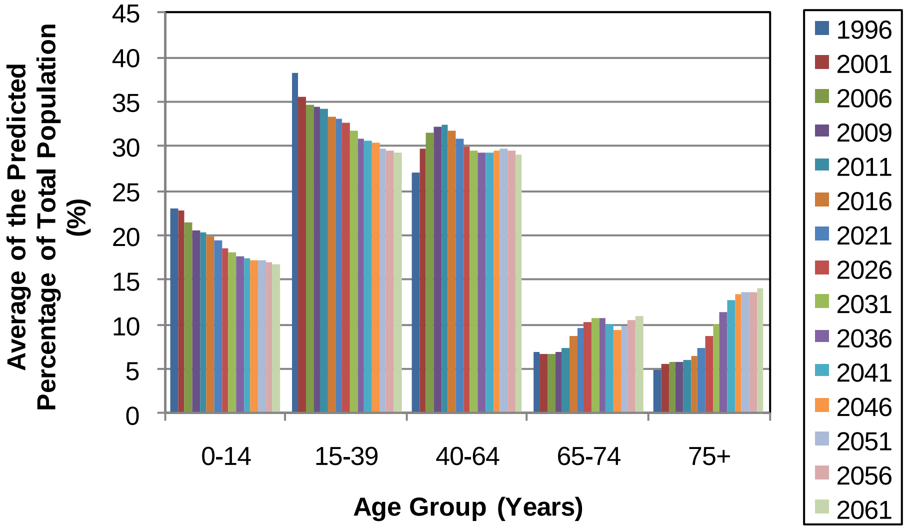

Figure 3: Averages of the predicted estimates for the age distribution, using broader age groups, of the New Zealand population (2011 to 2061) estimated from 2006 census data (SNZ 2009).

A summary of the number of New Zealand civilian fire fatalities and life threatening injuries reported for each age group various types of buildings from 2001 to 2009 is presented in Figure 4. (Challands 2010) The percentages of the total population and percentages of total civilian casualties are shown in Figure 6. The particular building types of interest are all residential structures, including detached houses and flats or apartment buildings, and institutional or healthcare buildings. The ratio of civilian fatalities to life threatening injuries for each age group is shown in Figure 5.

The numbers and percentages provide indications of trends within each metric over the age groups considered. For example, residential buildings consistently have a higher number of casualties than the aged care related buildings. In addition, for residential buildings, there is a marked increase in the ratio of fatalities to life threatening injuries for the age groups above 70 years compared to younger age groups. This may provide an indication of the relative frailty of the older age groups or may be related to the types of fires or situations that the victims were exposed to during the fire incidents that may be influenced by age. No matter the cause for the age related differences, there is a strong indication that serious fire related injuries are more likely to lead to death for older people living in residential occupancies than younger age groups in the same types of occupancies.

Outcomes from these two types of building cannot be directly compared, since the proportions of the population in each type of building and the building regulations are different. Therefore the influence of the number of casualties and occupants in each type of building is considered in terms of ratios of the average number of casualties per year (based on the 2001 – 2009 data set) to each 1,000,000 people in residential dwellings for each age group. A summary of the results are shown in Figure 7 for fatalities, in Figure 8 for life threatening injuries and in Figure 9 for serious fire casualties.

The significance of the small data set associated with fire casualties in institutional or healthcare buildings is obvious in all summary charts (i.e. Figure 7, Figure 8 and Figure 9) with the spikes in results. The small data set is included here only for general comparison with residential results and was not the focus of this study.

Residential results indicate that there is an increased risk of fire death for the age groups of 0 – 9, 70 – 79 and 80+ compared to the other age groups. This is in agreement with previous New Zealand (Chalmers 2000; Roen and Lloyd 2003) and international observations of higher fire risk for the very young and older segments of our communities, such as in the USA (Aherns 2003; USFA 2006) and Canada (Prolux et al. 1995; Proulx 2009).

There is no obvious trend between risk of life threatening injury and age (Figure 8). This may be a result of the relatively small data set and the relative fragility of the youngest and oldest of our community, where by life-threatening injuries may be more likely to lead to a fatality than recovery.

When considering serious fire casualties, combining fatalities and life threatening injuries, the 80+ age groups have a significantly higher ratio of casualties to population in private residential dwellings than any other age group (Figure 9).

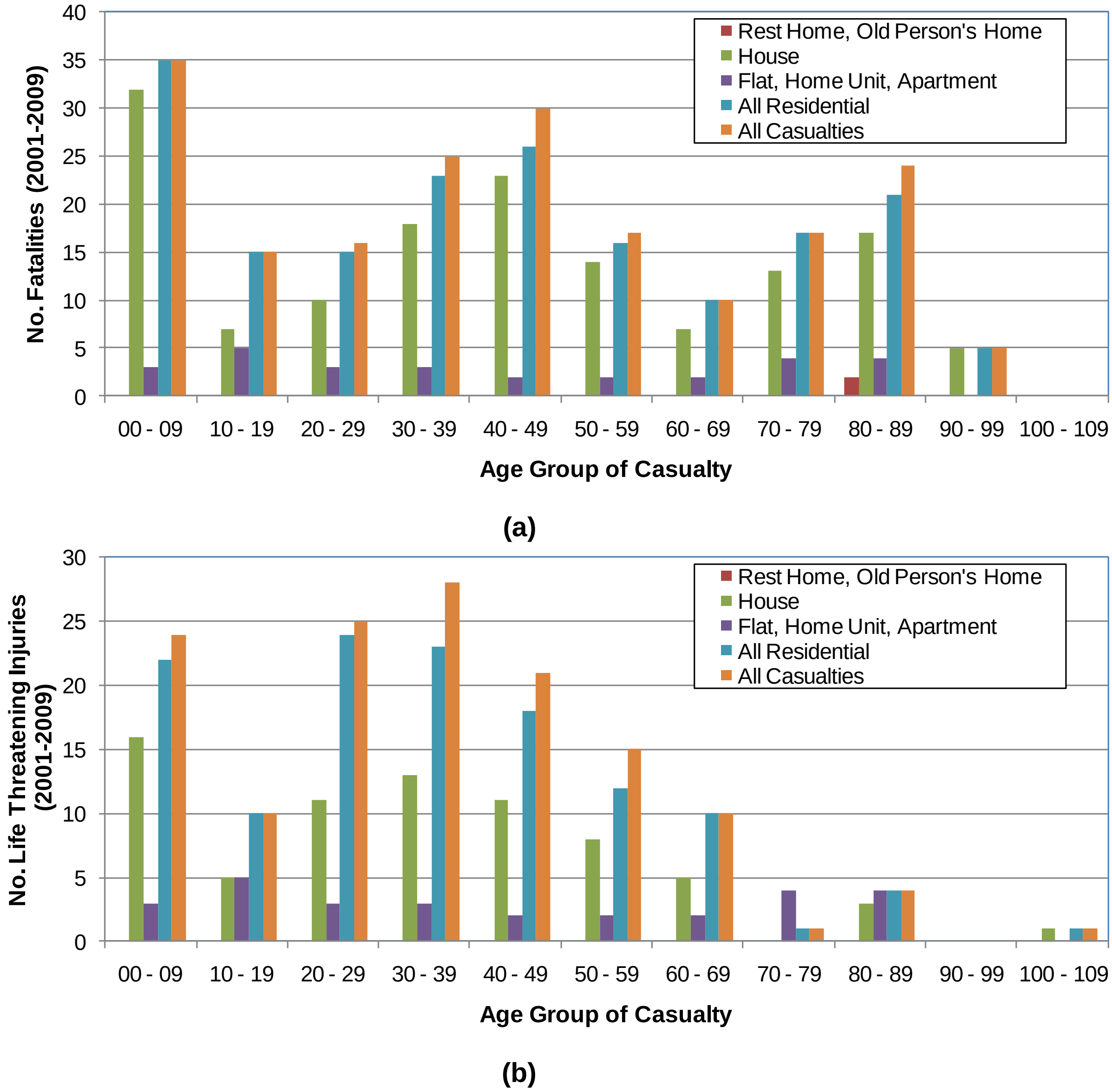

Figure 4: Number of (a) fatalities and (b) life threatening injuries for each age group in health care or institutional buildings and residential buildings in New Zealand from 2001 to 2009. (Challands 2010)

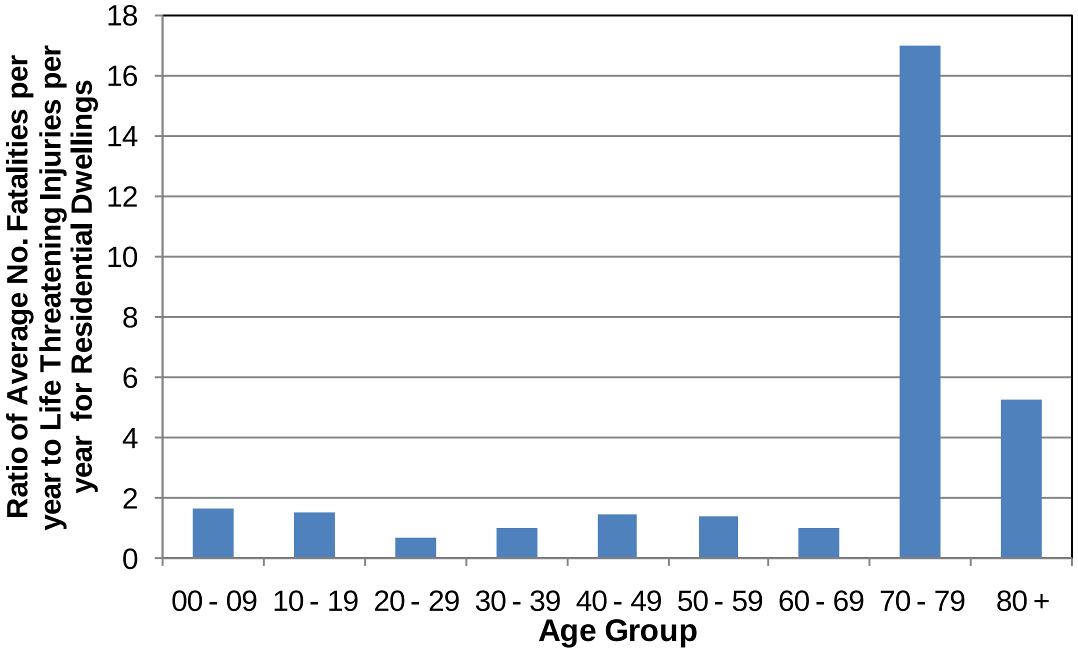

Figure 5: Ratio of the average number of fire fatalities per year to the average number of life threatening fire injuries per year for people living in residential dwellings. (Challands 2010)

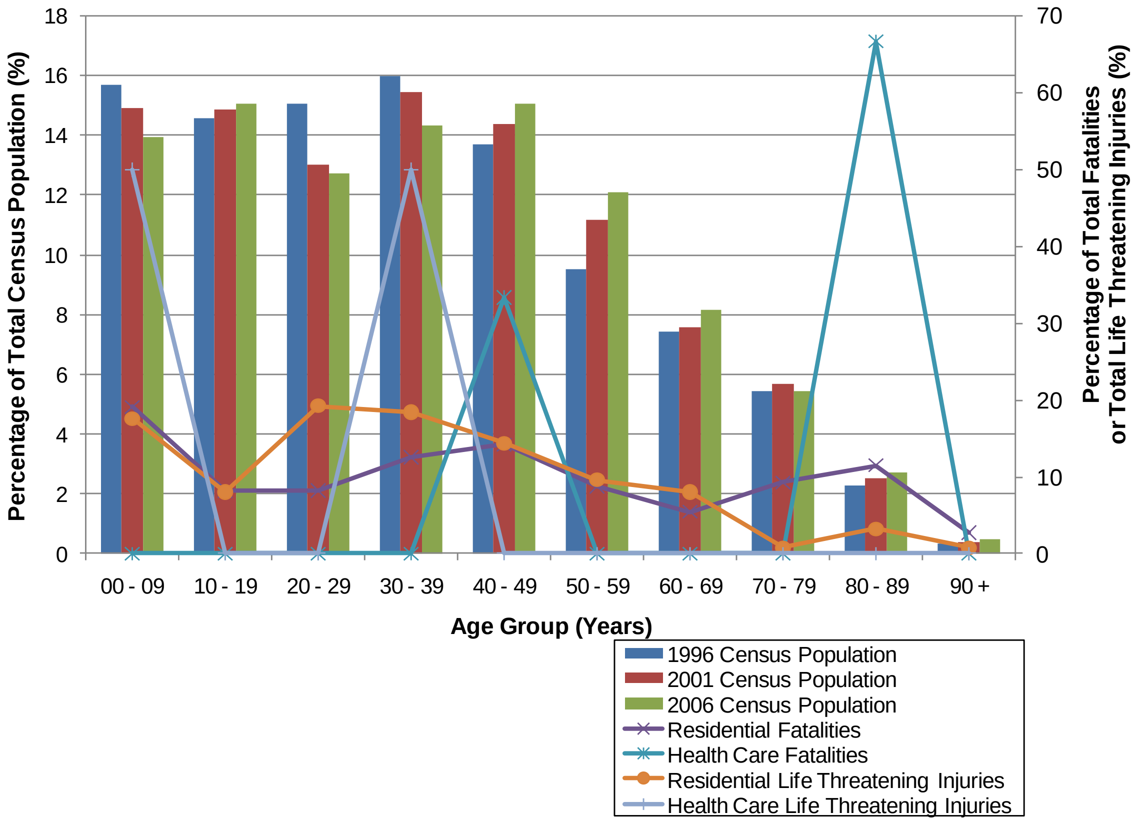

Figure 6: Percentages of total population for the 1996, 2001 and 2006 censuses (SNZ 2009) and percentages of total fire casualties from 2001 to 2009 (Challands 2010).

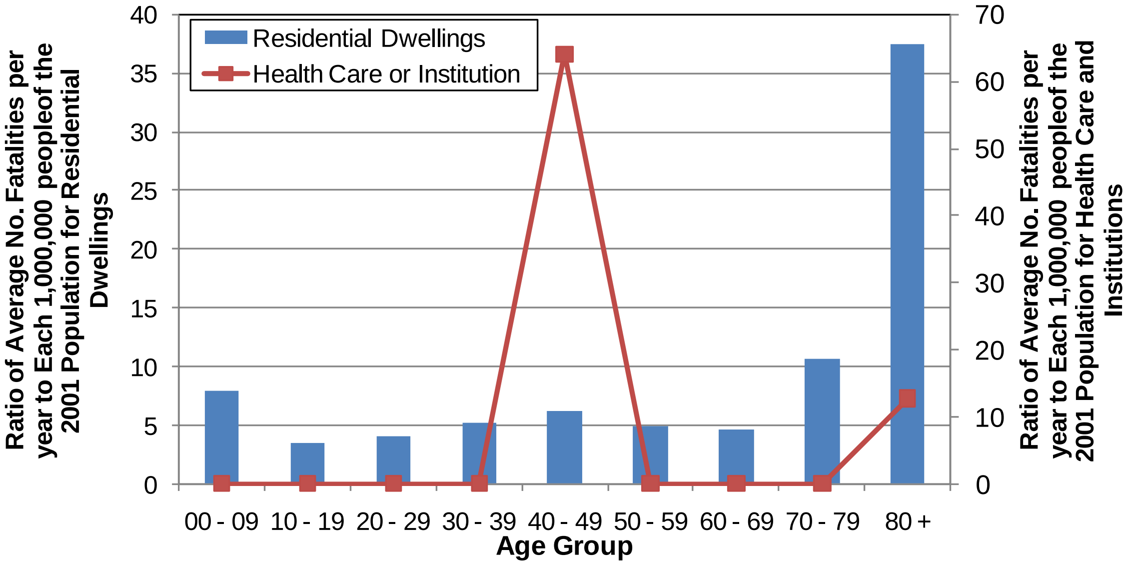

Figure 7: Ratios of the average number of fire fatalities per year (2001 – 2009) (Challands 2010) to number of people reported in residential dwellings and in healthcare or institutions (during 2006 Census) (SNZ 2002).

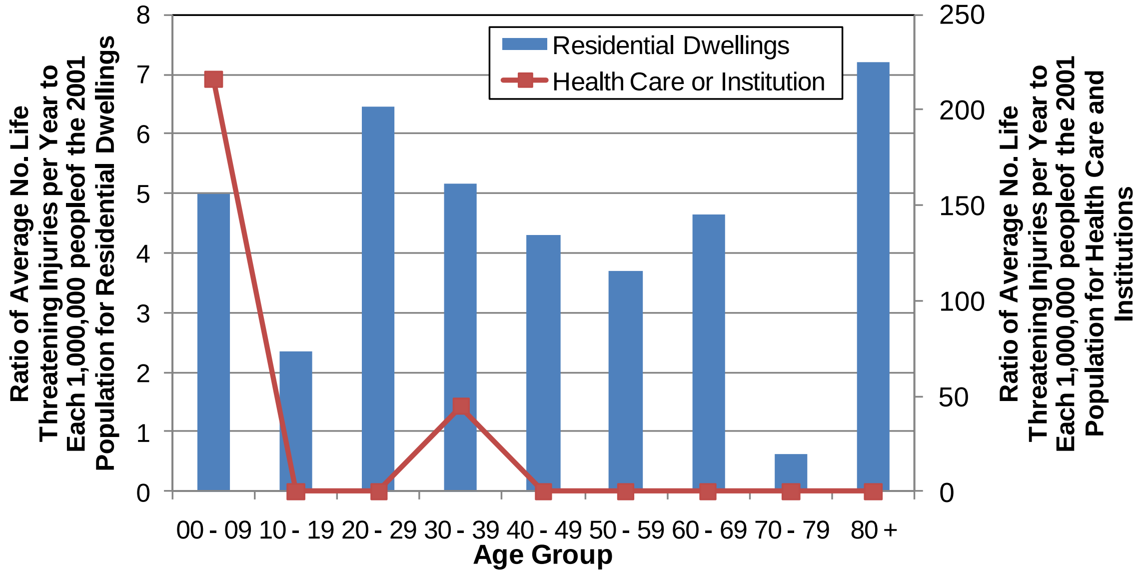

Figure 8: Ratios of the average number of fire life threatening injuries per year (2001 – 2009) (Challands 2010) to number of people reported in residential dwellings and in healthcare or institutions (during 2006 Census) (SNZ 2002).

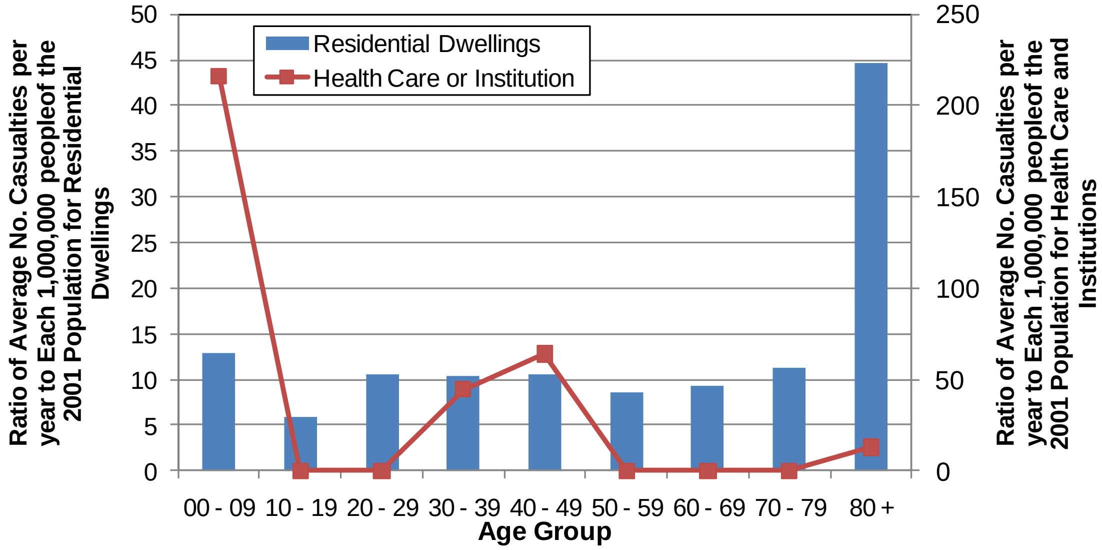

Figure 9: Ratios of the average number of fire casualties (i.e. fatalities and life threatening injuries) per year (2001 – 2009) (Challands 2010) to number of people reported in residential dwellings and in healthcare or institutions (during 2006 Census) (SNZ 2002)

2.1.1 Comparative Example: Victoria, Australia

New Zealand is a small population, therefore it is useful to consider other similar populations, so that trends can be compared. Any other similar population could be used for comparison. In this case, Victoria, Australia is included here as an example for comparison with trends observed in the New Zealand residential population.

The general proportions of the population of Victoria, based on age groups, compares well with that for New Zealand 1996, 2001 and 2006 censuses results (Figure 1 and Figure 2). The percentages of the total Victorian population by age group for the censuses (ABS 2008) are shown in Figure 10.

The proportions of fatalities per age group between Victoria and New Zealand (Figure 4(a)) again show similarities. The percentages of the total Victorian population by age group for the censuses (ABS 2008) are shown alongside the percentages of the total fire fatalities for each age group (Barnett 2008) in Figure 11.

The ratios of fire fatalities to size of the population for each age group for New Zealand (Figure 7) and Victoria are also similar. The percentages of the total populations for all people in Victoria, Australia for the censuses results by age group (ABS 2008) and ratio of the average number of yearly fire fatalities from 1998 to 2007 (Barnett 2008) to each 1,000,000 people of the average population for each age group (ABS 2008) are shown in Figure 12.

A selection of other socioeconomically related metrics are also summarised here for comparison. These include the percentage of principal source of household income and mean gross weekly income for households in Victoria by age group are shown in Figure 13, based on censuses results (ABS 2008). The percentages of residential household types and numbers of total renters by age group, based on censuses results (ABS 2008), are shown in Figure 14. The percentage of family household types by age group, based on censuses results (ABS 2008), is shown in Figure 15.

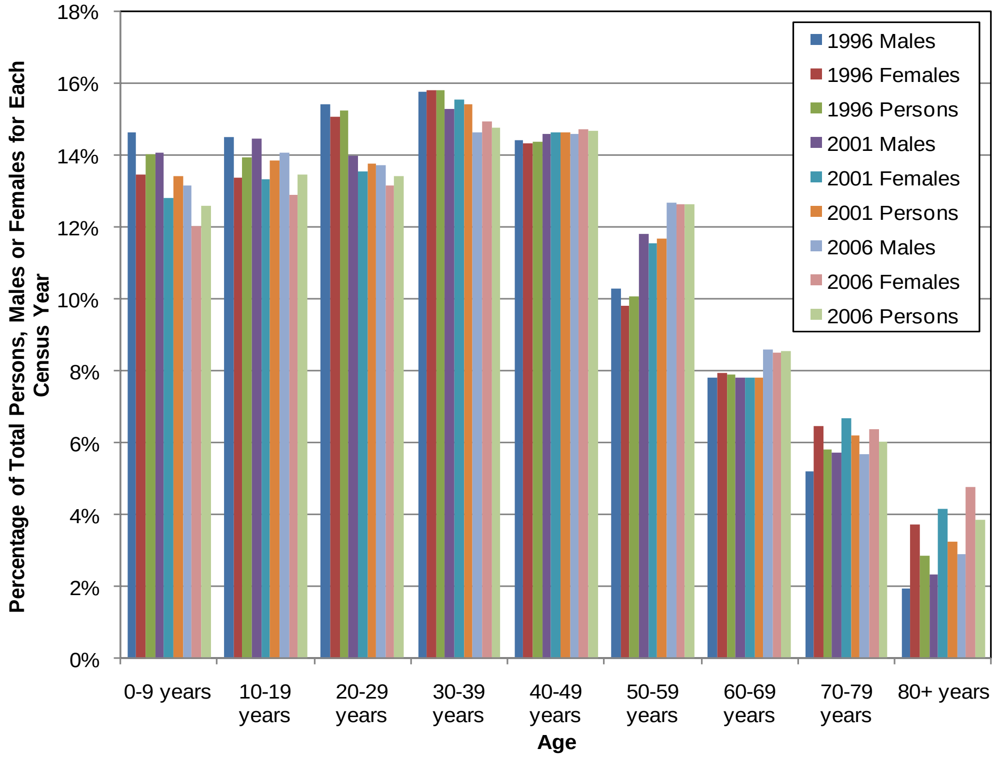

Figure 10: Percentages of the total populations for all census data, males and females in Victoria, Australia for the 1996, 2001 and 2006 censuses. (ABS 2008)

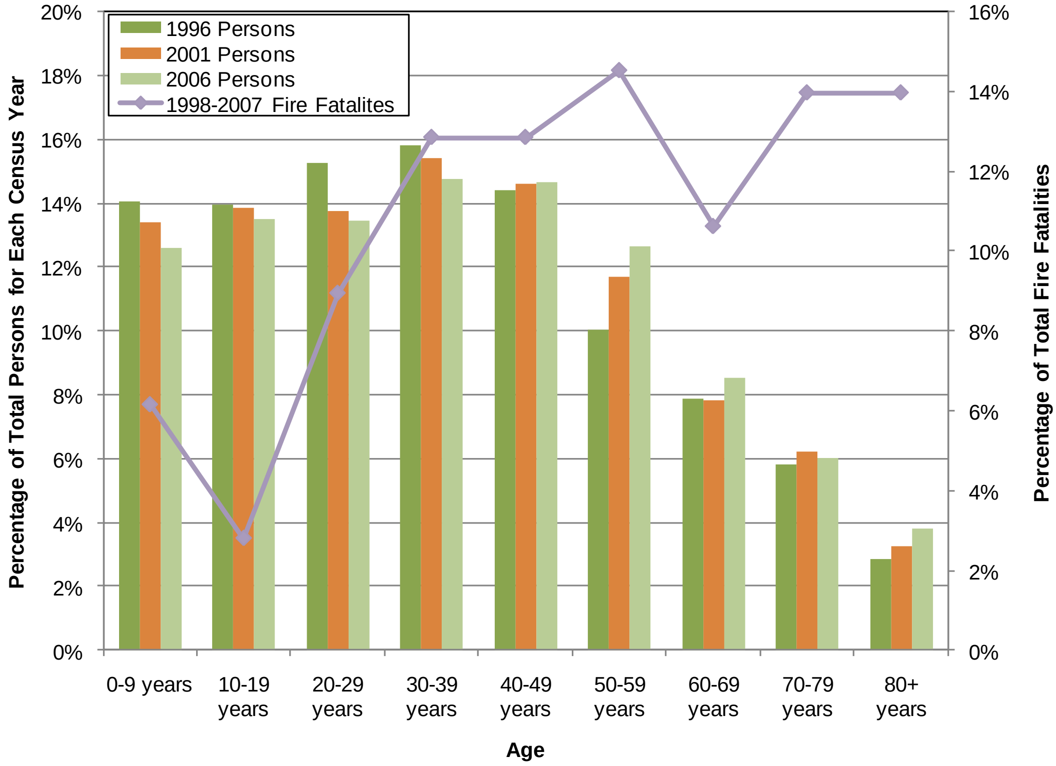

Figure 11: Percentages of the total populations for all people in Victoria, Australia for the 1996, 2001 and 2006 censuses by age group (ABS 2008) and percentage of total fire fatalities in Victoria, Australia from 1998 to 2007 (Barnett 2008).

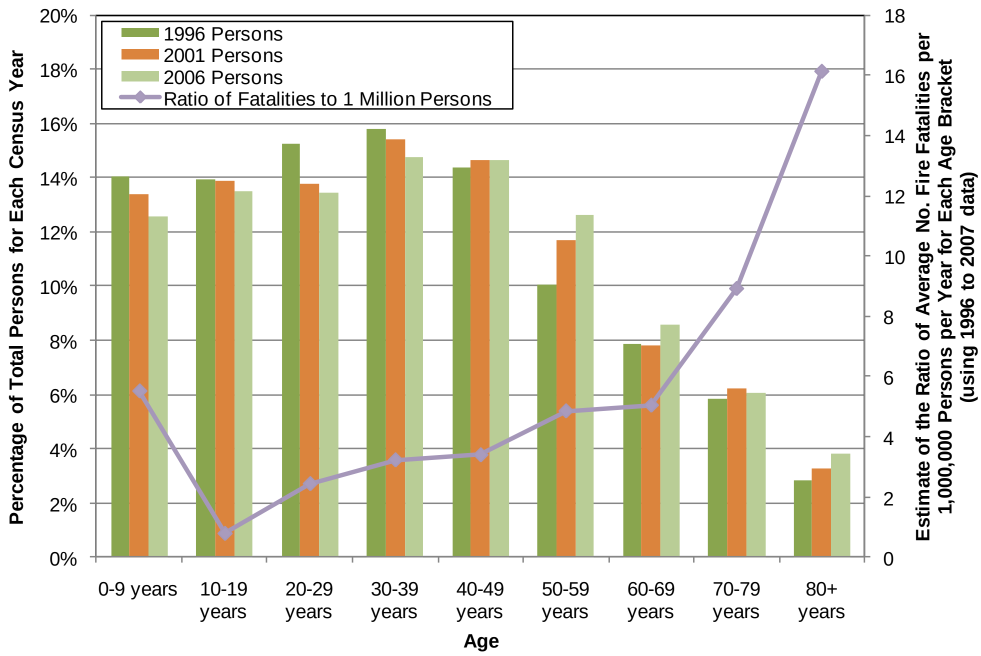

Figure 12: Percentages of the total populations for all people in Victoria, Australia for the 1996, 2001 and 2006 censuses by age group (ABS 2008) and ratio of the average number of yearly fire fatalities in Victoria, Australia from 1998 to 2007 (Barnett 2008) to each 1,000,000 people of the average population for each age group (ABS 2008).

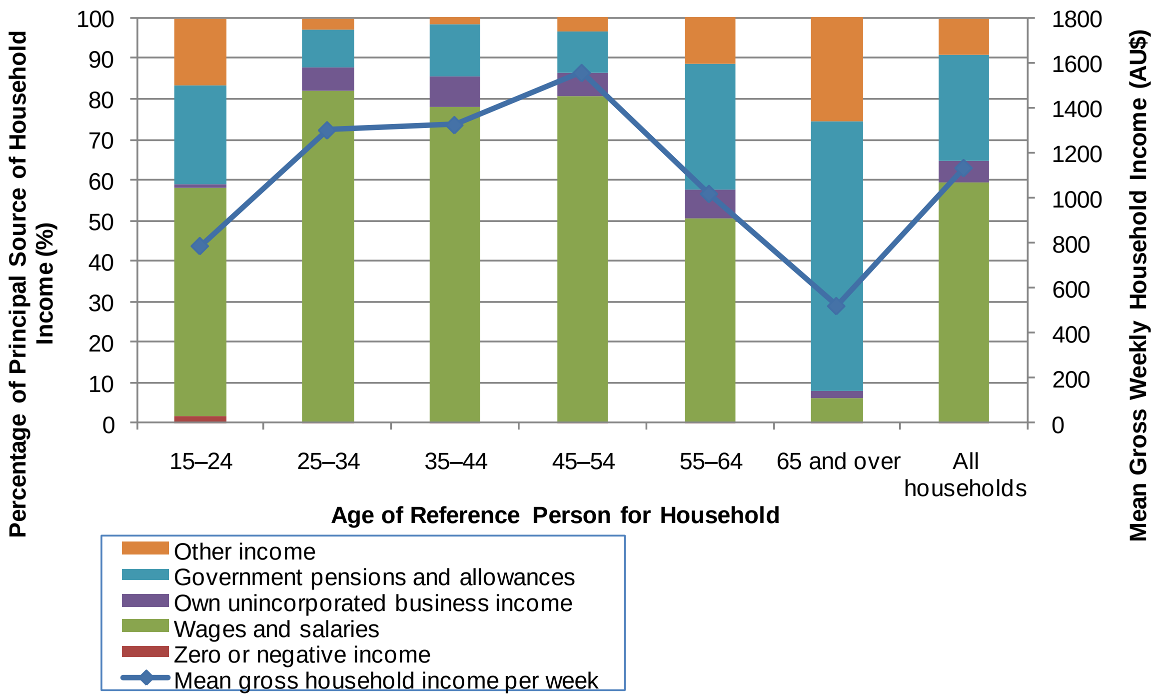

Figure 13: Percentage of principal source of household income and mean gross weekly income for households in Victoria, Australia for the 1996, 2001 and 2006 censuses by age group. (ABS 2008)

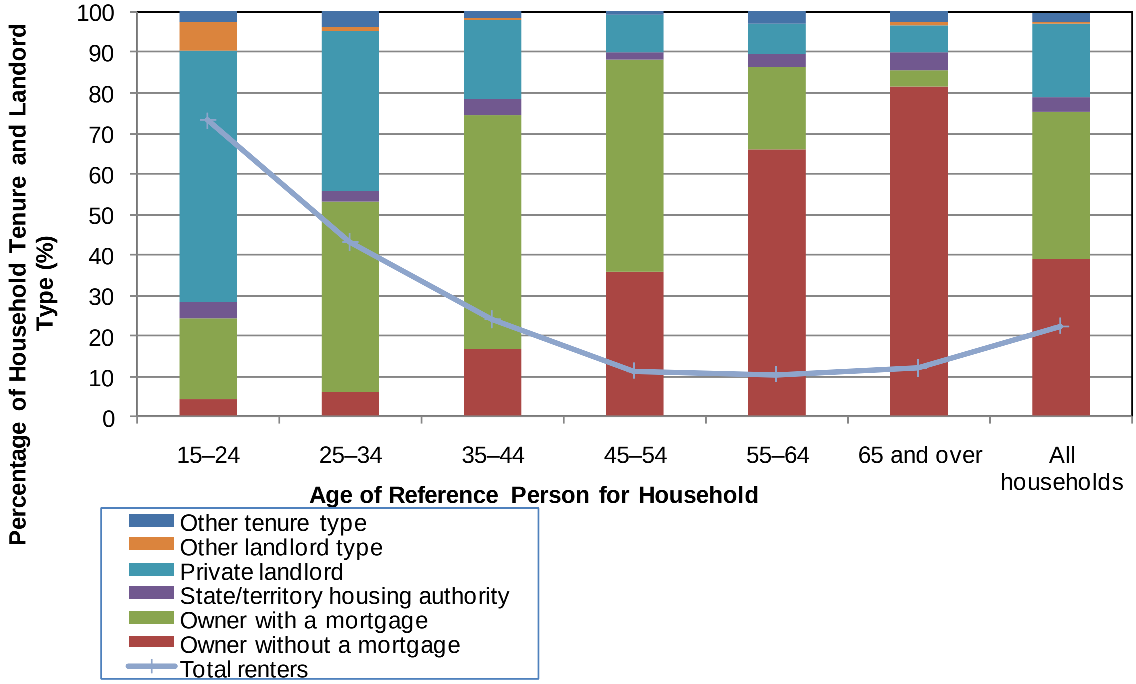

Figure 14: Percentage of residential household tenure type and number of total renters by age group for Victoria, Australia for the 1996, 2001 and 2006 censuses. (ABS 2008)

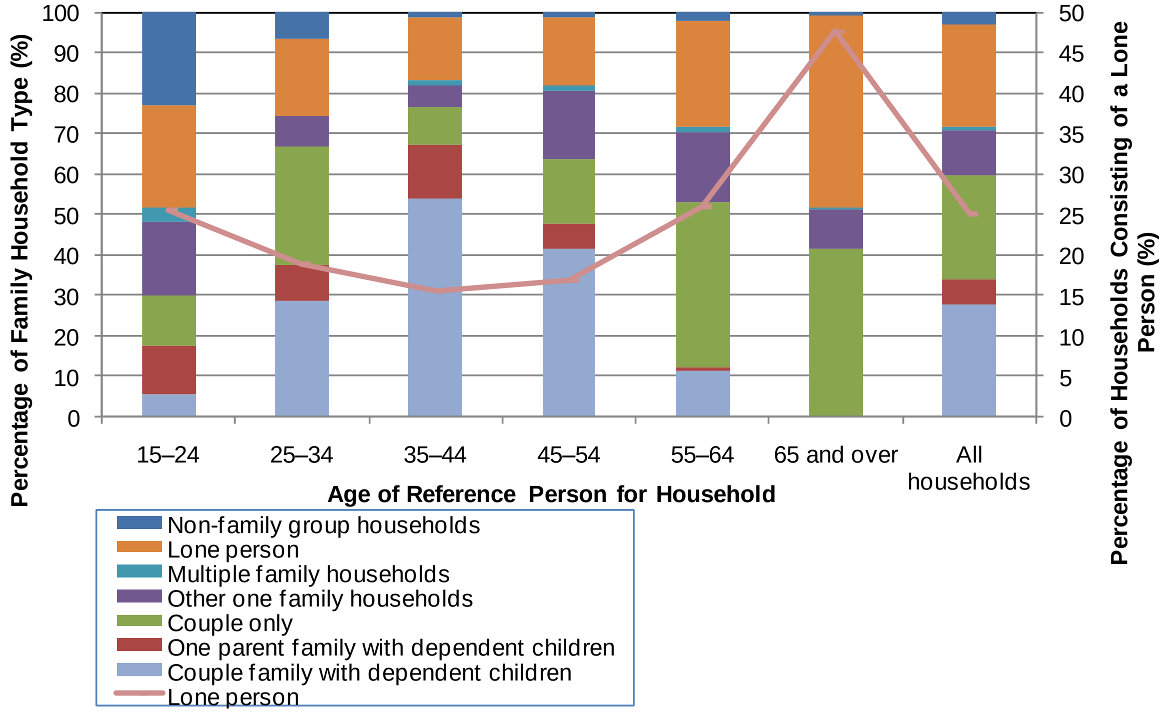

Figure 15: Percentage of family household types by age group for households in Victoria, Australia for the 1996, 2001 and 2006 censuses. (ABS 2008)

2.2 Older Adult Residential Population

Considering the elderly residential population, in the USA, the leading cause of fire deaths for older adults (aged 50 and older) in the USA is smoking-related fires (25%), followed closely by heating equipment fires (21%). (NFPA 2008)

USA statistics also indicate that older adults are more likely than other age groups to be intimately involved with the ignition source. (NFPA 2008) This consideration might be influential in selecting fast-acting fire protection features over slower options, or devices that prevent or reduce ignitions (e.g. thermostat cut-offs for stove-tops, heaters, etc.) when considering design fire scenarios for buildings with occupancies that include older adult populations.

Another consideration is that slips, trips and falls are a major source of injury and death in older adults, with one in three aged 65 years and over falling each year and rising to one in two for ages 80 years and over (Lilley, Arie and Chilvers 1995; ACC 2010). Therefore limiting trip and fall hazards in exitways (Ayres and Kelkar 2006; Zamora et al. 2008) and planning options and strategies to manage an evacuation in the case that one or more trip/fall accidents occur during an evacuation within an exitway. It is recognised that a fall of an escaping occupant, such as on an exit stair, may result in completely blocking the exitway (NFPA 2008). Design to limit fall-risk and mitigation of the outcome if one does occur may be incorporated, if the likelihood is sufficiently high based on the intended occupants.

Another way of attempting to quantify the similarities and differences between the evacuation characteristics of the 'general population' and segments of the community, such as residential older adults, may be to employ the risk factor identification approaches used in epidemiology, which has been used for the relation between fire injuries and alcohol consumption and smoking (e.g. Ballard, Koepsell and Rivara (1992)) and is commonly used in relation to health and illness. However it may be useful in a broader sense when considering the functionality of a segment of the community. This is discussed further on, when considering ways to measure capabilities and limitations that could be usefully incorporated into evacuation characteristics, if the quantitative values were available for the metrics.

2.3 Capabilities, Disabilities and Limitations

Age alone does not provide a direct measure of capability in terms of successful self-evacuation of a building (e.g. USFA (1999)). There are many aspects of an individual's ability to identify an incident, respond with a self-evacuation plan and execute a plan or gain assistance to escape (e.g. hearing impairments, sight impairments, etc. (FEMA 1999a and 1999b)). Also evacuation of a building is building specific and cannot be approached generically, and is instead a way of assessing the appropriateness of the fire safety design of a building.

Furthermore the older adult residential population also includes people with disabilities, where the impairments or limitations relate to other than just age-related changes in capabilities. Therefore disability-related information needs to be included in the description of older adult residential occupancies. Furthermore disability-related information may also be useful to provide comparison for areas of functionality where age-related information is limited or lacking. Therefore disabled population information is also included here.

When considering the range of capabilities of a building occupancy to successfully escape, one consideration is that the capabilities of 'persons with disabilities' cover a broad spectrum of attributes and levels of ability regarding self-rescue and typically does not include persons with temporary disabilities, who would usually be considered able-bodied.

In the context of this report, temporary (or short-term) disabilities are limitations of an individual's functionality that would reduce the likelihood of successful self-rescue in an emergency situation. Examples of persons with temporary disabilities would include a person with an injury that limits their mobility (e.g. on crutches with a sprained ankle, or broken leg, etc.), a pregnant lady, or a person on medication for an illness that is not expected to last more than 6 months, etc. Long-term disabilities that may not be captured under the typical application of 'persons with disabilities' include people with chronic heart disease or lung disease, etc. In the context of emergency egress, cases of this relate to the symptoms of the disease and/or medications where the individuals functionality is limited (Baggio 1999).

Therefore, in terms of describing the range of capabilities of an occupancy and the recommendations for building accessibility design, information and experience from designs for 'persons with disabilities' is included in this research as both an analogue and a comparative learning tool in combination with other information for designing residential occupancies targeting predominantly older persons.

In summary, age alone doesn't provide a direct measure of capability. Disability-related classification intersects with age but doesn't define age-related changes in functionality. Therefore disability-related information is included, both as an analogue and a learning tool.

2.3.1 Disabled or Impaired Occupants

Disability and impairment has a wide variety of definitions that cover the general areas of:

- Physical problems:
    - Mobility, e.g. movement on horizontal or inclined plains or stairs
    - Agility, e.g. getting in and out of bed or a chair
    - Dexterity, e.g. using door knobs, etc.
- Sensory problems:
    - Sight
    - Hearing
    - Touch
    - Smell
- Speaking problems:
    - Not able to speak or has difficulty being understood
- Cognitive problems:
    - Concentration
    - Comprehension
    - Memory
    - Ability to learn
- Psychiatric or psychological problems:
    - Socialising
    - Communication

Post-emergency case studies have included people with temporary or long-term medical conditions (NFPA 2008) that may not usually be included in the description of ‘persons with disabilities’ when designing a building for access. Such conditions include:

- Pregnancy,
- Cardiac conditions, and
- Respiratory conditions.

Therefore any person who has mobility, sensory or intellectual capabilities limited to some extent, either long-term or temporary, could be classified as disabled.

2.3.1.1 Characteristics based on Ranges of Capabilities and Limitations

Following is a summary of selected metrics where data has been collected that may be useful in the context of building access and possible emergency building evacuation for occupants with a range of capabilities and limitations.

The number of mobile disabled people by degree of mobility was reported by Boyce, Shields and Silcock (1999d) for Northern Ireland. The proportion of the total Northern Ireland mobile adult population with limited locomotion capabilities was approximately 7.6%. Those with limited dexterity totalled 3.0%, with limited sight was 2.9% of which 0.06% were blind, with limited hearing was 5.0% of which 0.1% were deaf, with mental or behavioural impairment was 2.7% of the total mobile Northern Ireland adult population. Furthermore percentages were also reported for a range of activities (Boyce, Shields and Silcock 1999d), as summarised in Table 2. However these values do not include the wider range of the population who experience temporary or long-term limitations that are not typically classified as disabilities.

Summaries for tests including people with a range of disabilities for walking a 50 m corridor with a 90° turn in Table 3, up a stairway in Table 4, and down a stairway in Table 5 (Boyce, Shields and Silcock 1999a) are included here for consideration of the ranges of average speed for each type of disability and aid combination and type of test. Boyce, Shields and Silcock (1999b) also investigated the ability and time to negotiate a door (single-leaf, 750 mm clear width), either pushing or pulling them open, with a range of closing forces for the combinations of disability and aid combinations. A similar investigation was also performed for the distance at which a sign (either non-illuminated, illuminated or LED) could be read by people with and without a sight disability (Boyce, Shields and Silcock 1999c). (NFPA 2008; SFPE 2008)

Another investigation reported the walking speeds of various types of building users at shopping centres. (Hokugo, Tsumura and Murosaki 2001) A summary of the collated results is included in Table 6. Similarly, ranges of walking speeds for different types of disabilities are summarised in Table 4.2.3 of the Fire Protection Handbook (NFPA 2008). However the values for these metrics are not as simple as means with ranges or sample standard deviations, as these vary with the individual as well as specific building features and local conditions, e.g. Figures 4.2.6 and 4.2.7 of NFPA (2008). Therefore care must be used when applying the values to the metrics for a specific application.

Table 2: Percentages of the total mobile adult population of Northern Island who have degrees of difficulty with a range of activities (Boyce, Shields and Silcock 1999d)

Action	Degree of Difficulty			Total Percentage of Mobile Adult Population
	Some	Great	Impossible	
Go up and down stairs	2.6	1.7	0.4	4.7
Climb outside steps	1.8	1.1	0.4	3.3
Cross door saddles	0.3	0.1	0.04	0.5
Go through doors	0.2	0.03	0.02	0.3
Turn door knobs	0.4	0.1	0.1	0.6

Table 3: Summary of speed on a horizontal surface for different types of mobility capabilities (Boyce, Shields and Silcock 1999a)

Group Description (No. Participants)	Mean Speed (m/s)	Range (m/s)	Inter-quartile Range (m/s)
All disabled (107)	1.00	0.10-1.77	0.71-1.28
All with mobility disability (101)	0.80	0.10-1.68	0.57-1.02
Un-aided (52)	0.95	0.24-1.68	0.70-1.02
Crutches (6)	0.94	0.63-1.35	0.67-1.24
Walking stick (33)	0.81	0.26-1.60	0.49-1.08
Walking frame or Rollator (10)	0.57	0.10-1.02	0.34-0.83
Without mobility disability (6)	1.25	0.82-1.77	1.05-1.34

Table 4: Summary of speed upwards on stairs for different types of mobility capabilities (Boyce, Shields and Silcock 1999a)

Group Description (No. Participants)	Mean Speed (m/s)	Range (m/s)	Inter-quartile Range (m/s)
All with mobility disability (30)	0.38	0.13-0.62	0.26-0.52
Un-aided (19)	0.43	0.14-0.62	0.35-0.55
Crutches (1)	0.22	-	-
Walking stick (9)	0.35	0.18-0.49	0.26-0.45
Rollator (1)	0.14	-	-
Without mobility disability (8)	0.70	0.55-0.82	0.55-0.78

Table 5: Summary of speed downwards on stairs for different types of mobility capabilities (Boyce, Shields and Silcock 1999a)

Group Description (No. Participants)	Mean Speed (m/s)	Range (m/s)	Inter-quartile Range (m/s)
All with mobility disability (30)	0.33	0.11-0.70	0.22-0.45
Un-aided (19)	0.36	0.13-0.70	0.20-0.47
Crutches (1)	0.22	-	-
Walking stick (9)	0.32	0.11-0.49	0.24-0.46
Rollator (1)	0.16	-	-
Without mobility disability (8)	0.70	0.45-1.10	0.53-0.90

Table 6: Summary of average walking speeds of users at two shopping centres (Hokugo, Tsumura and Murosaki 2001)

Group Description (No. Participants)	Mean Speed (Standard Deviation) (m/s)
Adult with difficulty walking	
Older adult walking very slowly (21)	0.83 (0.20)
Adult with walking disability (8)	0.78 (0.19)
Pregnant woman (4)	0.79 (0.12)
Older adult (155)	0.93 (0.41)
Older adult walking with another person (49)	0.88 (0.23)
Older adult walking alone (103)	0.96 (0.22)
Able-bodied adult	
Walking with another person (314)	0.93 (0.25)
Walking alone (446)	1.14 (0.27)

Some egress models include different parameter values for different segments of the population. For example, Simulex (Thompson and Marchant 1995; Thompson et al. 2003) and MASSEgress (Pan, Z. et al. 2006) have population types to represent an adult male, adult female, child and elderly person. The estimated parameter values are based on other than building evacuation sources.

For example, unimpeded travel speeds based on subway station egress results (Ando, Ota and Oki 1988; Kady, Gwynne and Davis 2009) used within Simulex were estimated for:

- a generic person to be 0.8 to 1.7 m/s,
- an adult male to be 1.35 ± 0.2 m/s,
- an adult female to be 1.15 ± 0.2 m/s,
- a child to be 0.8 ± 0.3 m/s, and
- an older person to be 0.9 ± 0.3 m/s.

Similarly, based on pedestrian results (Eubanks & Hill 1998), the average travel speeds used within MASSEgress were estimated for:

- a generic person to be 1.30 m/s, with a maximum when running on the flat in the open of 4.10 m/s,
- an adult male to be 1.35 m/s, with a maximum of 4.10 m/s for running on the flat in the open,
- an adult female to be 1.15 m/s, with a maximum of 4.10 m/s for running on the flat in the open,
- a child to be 0.90 m/s, with a maximum of 3.40 m/s for running on the flat in the open, and

- an older person to be 0.80 m/s, with a maximum of 2.75 m/s for running on the flat in the open.

2.3.1.2 Estimated Response of Elderly Occupants in Emergency Evacuation Situations

Instead of involving elderly people in stressful situations of evacuations or drills, one example of a method for estimating the response of elderly occupants in emergency evacuation simulations is the use of ‘temporary elderly’ evacuees (Furukawa et al. 2007; Okada et al. 2009).

These ‘temporary elderly’ were created using equipment to be worn by younger people to simulate elderly people by reducing the sight (using goggles), hearing (using earplugs), touch (using a glove) and mobility (using joint restricting bands, wrist and ankle weights and a walking stick) of the person. The reproducibility of the equipment to be used to simulate the evacuation capability of elderly people (target as approximately 75 to 80 year old people) has been verified (Furukawa et al. 2007), but the fatigue of the equipment wearer compared to an actual elderly evacuee was not expected to be representative as it had not been compared at the time of the analysis. (Furukawa et al. 2007; Okada et al. 2009)

Average upward walking velocity on a flight of stairs (rise of 0.15 m, tread of 0.3 m, width of steps 2.5 m, width between handrails 2.538 m, horizontal length of steps 14.5 m with a 1.8 m landing midway, vertical height of 5.7 m), a short escalator (rise of 0.2 m, tread of 0.4 m width of steps 0.99 m, width between handrails 1.19 m, horizontal length of 12.276 m, vertical height of 5.7 m) and a long escalator (rise of 0.2 m, tread of 0.4 m, width of steps 1.015 m, width between handrails of 1.2 m, horizontal length of 49.5 m, vertical height of 22.0 m) was reported based on a group of university students (with average age of 21 years), where 12 wore the equipment for the ‘temporary elderly’ and 38 did not. The escalators were considered both running (at 0.5 m/s) and still. The simulated evacuees were considered in four configurations: walking solo, a square configuration of 7 parallel lines with the ‘temporary elderly’ arranged randomly, a pair of 2 parallel lines with the ‘temporary elderly’ arranged randomly, and a pair of 2 parallel lines with the ‘temporary elderly’ only located in the right hand line. (Okada et al. 2009)

A summary of average measurements from the range of experiments is included in Table 7. Distributions of the average upward walking speeds of each of the participants of the still elevator with two parallel lines of randomly located unimpeded students and ‘temporary elderly’ are shown in Figure 16. Distributions for the unimpeded students and the ‘temporary elderly’ for the configuration with all the ‘temporary elderly’ located in the right-hand side of the two parallel lines of test-evacuees are shown in Figure 17. (Okada, et al. 2009)

This set of simulated evacuation results using ‘temporary elderly’ to estimate the impact of limited sensory and mobility function on individuals showed both a lower average walking speed and a narrower range of the observed distributions of average walking speed for the individuals within the group. Although this data is a small size and the impact of endurance/fatigue was not incorporated in the simulated ‘temporary elderly’ approach described here, there is still a marked difference between the unimpeded students and those with the simulated limits in aspects of functionality during the evacuation tests.

Distributions were also published for the still short escalator as approached by a group of participants. The entrance to the escalator was approached in the square formation shown in the top right of Figure 18. The location of the test participants wearing the temporary elderly equipment was chosen without a conscious pattern. (Okada et al. 2009)

Table 7: Summary of simulated evacuation experiment results including 'temporary elderly' (Okada, et al. 2009)

		Simulated Evacuee Configuration							
		Solo		Square Configuration		2 Parallel Lines with random 'temporary elderly' [a]		2 Parallel Lines with 'temporary elderly' on the right [b]	
Type of Evacuee		Student	Temp. Elderly	Student	Temp. Elderly	Student	Temp. Elderly	Student	Temp. Elderly
Simulated Escape Route Description	Stairs	0.75	0.51	0.68	0.54	-	-	-	-
	Short Escalator Running	1.21	0.93	0.95	0.90	-	-	-	-
	Short Escalator Still	0.78	0.53	0.54	0.48	0.55	0.51	0.68	0.50
	Long Escalator Running	1.26	0.93	1.01	0.93	-	-	-	-
	Long Escalator Still	0.79	0.50	0.54	0.47	-	-	-	-

Table Notes:
[a] The evacuee configuration is as shown in the schematic included in Figure 16.
[b] The evacuee configuration is as shown in the schematic included in Figure 17.

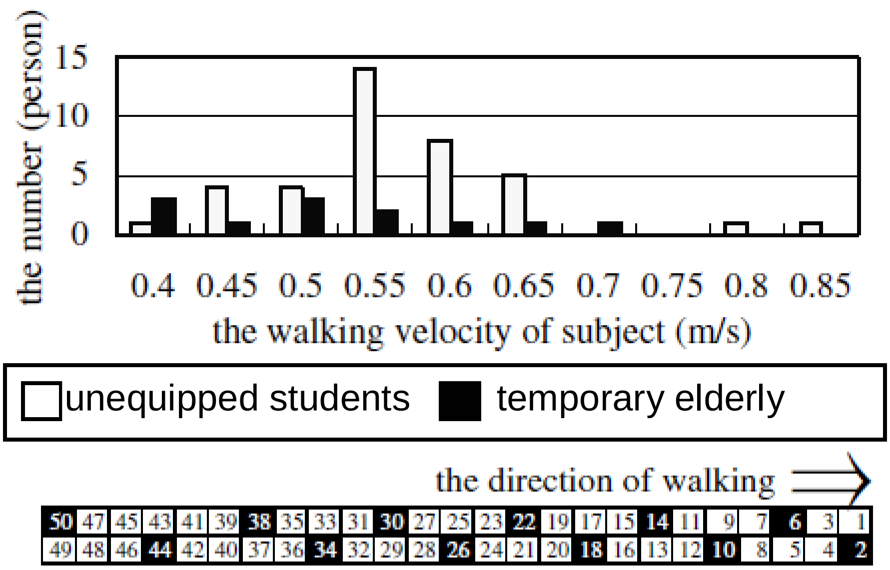

Figure 16: Distribution of average upward walking speeds of the unequipped students and 'temporary elderly' for third configuration of people. Extracted from Okada, et al., (2009).

The distribution of the average walking speed of the 12 temporary elderly participants ranged from 0.38 to 0.60 m/s. The average walking speed for the 38 students without additional equipment ranged from 0.41 to 0.79 m/s. These ranges of average walking speed include people who were restricted because they did not overtake slower moving people, who were walking abreast. (Okada et al. 2009)

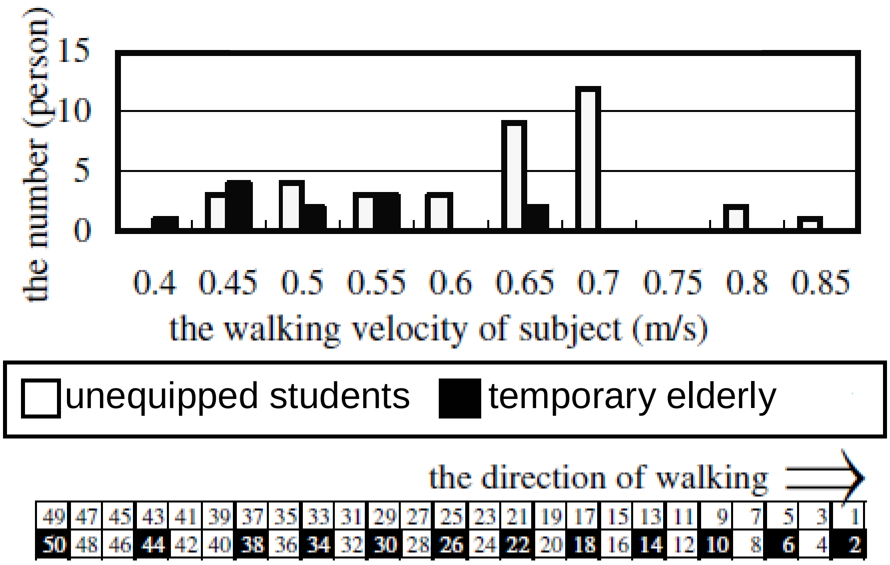

Figure 17: Distribution of average upward walking speeds of the unequipped students and 'temporary elderly' for fourth configuration of people. Extracted from Okada, et al., (2009).

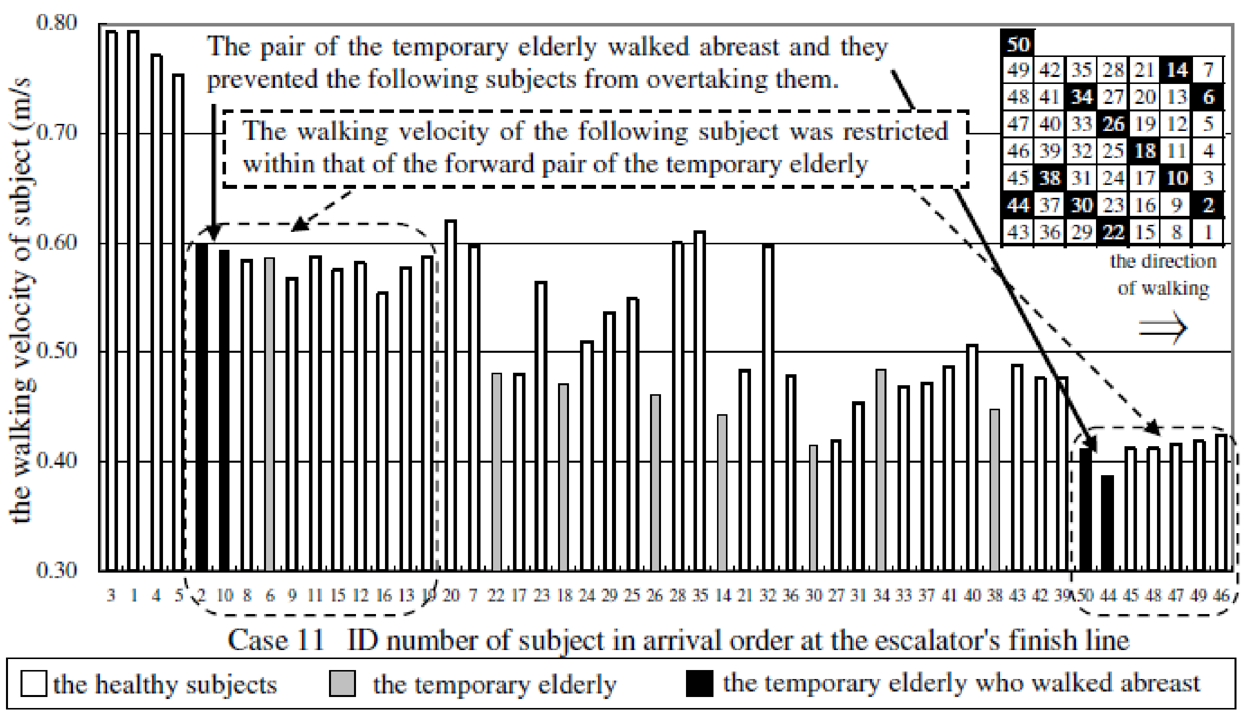

Figure 18: The walking velocity of 50 individual test participants in the order of those who reached the top of the static short escalator first. Extracted from Okada et al. (2009).

2.3.2 New Zealand Disability Statistics

The percentages of the New Zealand population with disabilities based on census responses for 1996, 2001 and 2006 are summarised in Table 8. (SNZ 2007) Of the people with reported disabilities in 2006 82% were adults living in housing (539,200 people), 5% were adults in residential care facilities (31,100 people), and 14% were children (under 15 years) living in households (90,000 people). (SNZ 2007)

In 2006, one-third of all people with disabilities were in the 65+ year age group. (SNZ 2007)

The description of disability used in this survey was "...any restriction or lack (resulting from impairment) of ability to perform an activity in the manner or within the range considered normal for a human being." (SNZ 2007) Therefore the results for individuals are relative to what the person perceives he or she should be capable of, or by comparison with their peers. Therefore the results of personal subjective assessment need to be taken in context (Collantes and Mokhtarian 2007; Mollaoglu, Tuncay and Fertelli 2010). Similarly the summary results for each age group are the levels of disability relative to what the individual participants within that group perceived they should be capable of at their age. Therefore there would be additional age-related changes in capabilities that would need to be applied to each set of results before they could be used to estimate the characteristics of each age-group.

Disabilities were not included if an assistive device (e.g. glasses) eliminated the person's limitations. Furthermore disabilities were only included if the associated limitation had been experienced for 6 months or more or was expected to last 6 months or more. (SNZ 2007) Therefore no temporary limits in functionality (e.g. temporary injury or illness and associated side-effects from medications, etc.) were included in this survey.

The following definitions of disability were used, where a person (SNZ 2007):

- Hearing – cannot hear or has difficulty hearing a conversation with at least three other people.
- Seeing – when wearing corrective lenses, cannot see or has difficulty seeing ordinary newsprint and/or seeing a person's face across a room.
- Mobility – cannot walk or has difficulty walking:
    - 350 m without resting,
    - up or down a flight of stairs,
    - while carrying a 5 kg object for 10 m,
    - from room to room, or
    - standing for longer than 20 min at a time.
- Agility – cannot or has difficulty:
    - bending over to pick something up off the floor,
    - dressing or undressing themselves,
    - cut their own toe-nails,
    - grasp or handle small objects like scissors,
    - reach in any direction,

- cut their own food, or
- get in or out of bed.

- Speaking – cannot or has difficulty speaking or being understood.
- Intellectual – needs support or help from people or organisations, or has been to a special school or received special education because of an intellectual disability or handicap.
- Psychiatric/ Psychological – has a long-term emotional, psychological or psychiatric conditions that leads to difficulty or stops the person doing everyday activities that people their age can usually do, including communicating, mixing with others or socialising.
- Other – has long-term conditions or health problems that causes them ongoing difficulty with their ability to learn or remember, or causes them difficulty with or stops them from doing everyday activities that other people of their age can usually do.

Some of the results from the New Zealand 2006 Disability Survey are summarised in the following tables for the age groups of 0 to 14 years, 15 to 44 years, 45 to 64 years and 65+ years (Table 8). The disabilities reported for adults, 65+ years, living in private households is summarised for the cause of disability (Table 9), the type of disability (Table 10), the level of support required (Table 11) and the total personal income per year (Table 12) compared to the total New Zealand population (i.e. with and without disabilities) for the same age group.

Table 8: Summary of the percentages of each age group with a reported disability for the New Zealand Census of 1996, 2001 and 2006 (all New Zealanders). Extracted from SNZ (2007).

Census Year	Percentage of Each Age Group with a Reported Disability				Percentage of the Total Population with a Reported Disability
	0-14 years	15-44 years	45-64 years	65+ years	
1996	11%	12%	25%	52%	20%
2001	11%	13%	25%	54%	20%
2006	10%	9%	20%	45%	17%

Table Note: It was suggested that the apparent decline in percentage values of disabled people reported for 2006 compared to previous year was due to factors related to the way the 2006 survey was conducted, changes in peoples' perceptions of disabilities, as well as a possible actual change in peoples' level of disability. Therefore numbers are only included for general purposes and use of these values is recommended with care.

Table 9: Cause of disability for people in the age group of 65+ years in households (SNZ 2010a)

Cause of Disability	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Disease or Illness	63,400	33	14
Existed at Birth	1,500	1	<1
Natural Aging	61,800	32	13
Accident or Injury	28,900	15	6
Other Cause	26,700	14	6
Not Specified	7,900	4	2

Table Note: People may have more than one cause of disability.

Table 10: Type of disability for people in the age group of 65+ years in households (SNZ 2010a)

Type of Disability	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Hearing	35,400	19	8
Seeing	9,500	5	2
Mobility	88,400	46	19
Agility	31,400	16	7
Intellectual	-*	-*	-*
Psychiatric/ Psychological	4,300	2	1
Speaking	-*	-*	-*
Remembering	6,800	4	1
Learning	-*	-*	-*
Other	13,400	7	3

Table Note: People may have more than one type of disability.
* Statistical error associated was too large to be reasonably included.

Table 11: Support level for people in the age group of 65+ years in households (SNZ 2010a)

Level of Support	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Low support needs	55,300	29	12
Medium support needs	105,000	55	23
High support needs	30,700	16	7
Total with disability	190,900	100	41

Table 12: Personal total income for people in the age group of 65+ years in households (SNZ 2010a)

Total Personal Yearly Income	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Less than $15,001	85,700	45	42
$15,001 to $30,000	62,000	32	32
$30,001 to $50,000	13,300	7	10
$50,001 or more	7,900	4	6
Not Stated	22,100	12	10

2.3.2.1 Statistics for Other Residential Age Groups

A summary of the statistics for the younger segments (children of 0 to 14 years, adults of 15 to 44 years and 45 to 64 years) of the community living in residential households (i.e. no level of care is provided) are also included for comparison with the older age group.

For children of 0 to 14 years, the cause of disability, type of disability, and level of support required are presented in Table 13, Table 14 and Table 15 respectively. (SNZ 2007; SNZ 2010a)

For adults of 15 to 44 years, the cause of disability, type of disability, level of support required, and personal income per year are presented in Table 16, Table 17, Table 18 and Table 19 respectively. (SNZ 2010a)

For adults of 45 to 64 years, the cause of disability, type of disability, level of support required, and personal income per year are presented in Table 20, Table 21, Table 22 and Table 23 respectively. (SNZ 2010a)

Of the population of each age group where a disability was reported, the cause of disability reported as ‘existed at birth’ decreases as the age groups increase in years, from 52% of 0 to 14 year olds with a disability, to 17% of 15 to 44 year olds, to 9% of 45 to 64 year olds, to 1% of 65+ year olds with a disability. ‘Natural aging’ increases with an increase in years, where only the age groups of 45 to 64 years (11%) and 65+ years (32%) include it as a cause of disability, where a disability was reported. ‘Disease or illness’ remained approximately similar (between 23 and 33%) for each age group considered, where 26% of the 0 to 14 year age group, 23% of the 15 to 44 year age group, 25% of the 45 to 64 year age group and 33% of the 65+ year age group included it as a cause of disability, where a disability was reported. ‘Accident or injury’ was lowest for the 65+ years age group (15% of the 65+ year age group with a reported disability), compared to all other age groups.

Of the total population for each age group (including people with and without disabilities), generally the reported limitations are slightly higher for the 0 to 14 year (children) age group compared to the 15 to 44 year (young adult) age group. However overall the general trend is toward increased reported limitations for each type of disability considered, as shown in Figure 19, Figure 20 and Figure 21 for numbers of people who reported each type of disability, the percentage of prevalence of each type of disability of the people with disabilities and the percentage of prevalence of each type of reported disability for the whole population for each age group considered respectively.

The distributions of disabilities compared to all people in each age group is shown in Figure 22, however these do not include the expected level of disability that individuals expect to encounter based on their age alone. Therefore the actual level of limitation expected for at least the age groups of 45 to 64 years and 65+ years would be higher than shown in Figure 22 when compared to one set of expected capabilities (e.g. if compared to the 15 to 44 year olds, then the 0 to 14 year olds limitations may be higher than shown in Figure 22 along with the 65+ year age group). In the 2006 Disability Survey, the expectation of what capabilities and limitations that they would have for their age without any disabilities was based on each individual survey-respondent's expectations, therefore these results are to be taken in terms of general trends and not specific values.

Table 13: Cause of disability for children in the age group of 0 to 14 years in households (SNZ 2007)

Cause of Disability	Number of Children	Percentage of Disabled Children in Age Group (%)	Percentage of Total Children in Age Group (%)
Disease or Illness	23,500	26	3
Existed at Birth	46,600	52	5
Natural Aging	-	-	-
Accident or Injury	17,100	19	2
Other Cause	2,500	3	<1
Not Specified	10,600	12	1

Table Note: People may have more than one cause of disability.

Table 14: Type of disability for children in the age group of 0 to 14 years in households (SNZ 2010a)

Type of Disability	Number of Children	Percentage of Disabled Children in Age Group (%)	Percentage of Total Children in Age Group (%)
Hearing	13,300	15	2
Seeing	11,400	13	1
Use of Technical Aids	9,500	11	1
Chronic Health Problem	35,000	39	4
Intellectual	16,900	19	2
Psychiatric/ Psychological	19,300	21	2
Special Education	41,000	46	5
Speaking	19,300	21	2
Other	13,500	15	2

Table Note: People may have more than one cause of disability.

Table 15: Support level for children in the age group of 0 to 14 years in households. Extracted from SNZ (2007).

Level of Support	Number of Children	Percentage of Disabled Children in Age Group (%)	Percentage of Total Children in Age Group (%)
Low support needs	36,600	41	4
Medium support needs	40,600	45	5
High support needs	12,800	14	1
Total with disability	90,000	100	10

Table 16: Cause of disability for people in the age group of 15 to 44 years in households (SNZ 2010a)

Cause of Disability	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Disease or Illness	32,500	23	2
Existed at Birth	23,300	17	1
Natural Aging	-*	-*	-*
Accident or Injury	37,700	27	2
Other Cause	33,300	24	2
Not Specified	13,600	10	1

Table Note:
People may have more than one type of disability.
* Statistical error associated was too large to be reasonably included.

Table 17: Type of disability for people in the age group of 15 to 44 years in households (SNZ 2010a)

Type of Disability	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Hearing	19,000	13	1
Seeing	5,500	4	<1
Mobility	31,100	22	2
Agility	16,200	11	1
Intellectual	5,200	4	<1
Psychiatric/ Psychological	27,700	20	2
Speaking	3,700	3	<1
Remembering	6,400	5	<1
Learning	8,900	6	1
Other	17,300	12	1

Table Note: People may have more than one type of disability.

Table 18: Support level for people in the age group of 15 to 44 years in households (SNZ 2010a)

Level of Support	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Low support needs	69,300	49	4
Medium support needs	55,400	39	3
High support needs	16,500	12	1
Total with disability	141,200	100	9

Table 19: Personal total income for people in the age group of 15 to 44 years in households (SNZ 2010a)

Total Personal Yearly Income	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Less than $15,001	49,800	35	31
$15,001 to $30,000	34,300	24	19
$30,001 to $50,000	29,300	21	23
$50,001 or more	11,900	8	16
Not Stated	15,900	11	11

Table 20: Cause of disability for people in the age group of 45 to 64 years (SNZ 2010a)

Cause of Disability	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Disease or Illness	52,300	25	5
Existed at Birth	18,500	9	2
Natural Aging	22,600	11	2
Accident or Injury	53,600	26	5
Other Cause	46,100	22	4
Not Specified	13,900	7	1

Table Note: People may have more than one cause of disability.

Table 21: Type of disability for people in the age group of 45 to 64 years in households (SNZ 2010a)

Type of Disability	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Hearing	64,800	23	5
Seeing	9,400	5	1
Mobility	62,500	30	6
Agility	36,200	17	3
Intellectual	1,900	1	<1
Psychiatric/ Psychological	13,200	6	1
Speaking	1,900	1	<1
Remembering	7,600	4	1
Learning	5,400	3	1
Other	21,700	10	2

Table Note: People may have more than one type of disability.

Table 22: Support level for people in the age group of 45 to 64 years in households (SNZ 2010a)

Level of Support	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Low support needs	84,700	41	8
Medium support needs	102,300	49	10
High support needs	20,100	10	2
Total with disability	207,000	100	20

Table 23: Personal total income for people in the age group of 45 to 64 years in households (SNZ 2010a)

Total Personal Yearly Income	Number of Adults	Percentage of Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
Less than $15,001	72,800	35	20
$15,001 to $30,000	42,200	20	19
$30,001 to $50,000	43,100	21	26
$50,001 or more	30,100	15	26
Not Stated	18,800	9	8

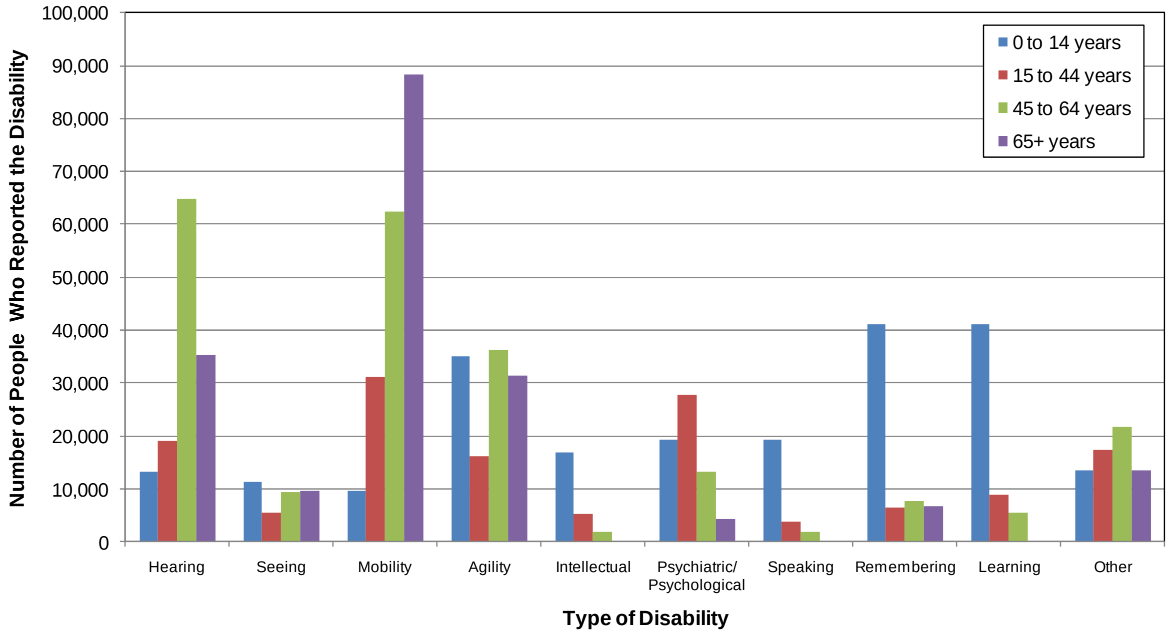

Figure 19: Number of people who reported each type of disability, by age group (SNZ 2010a)

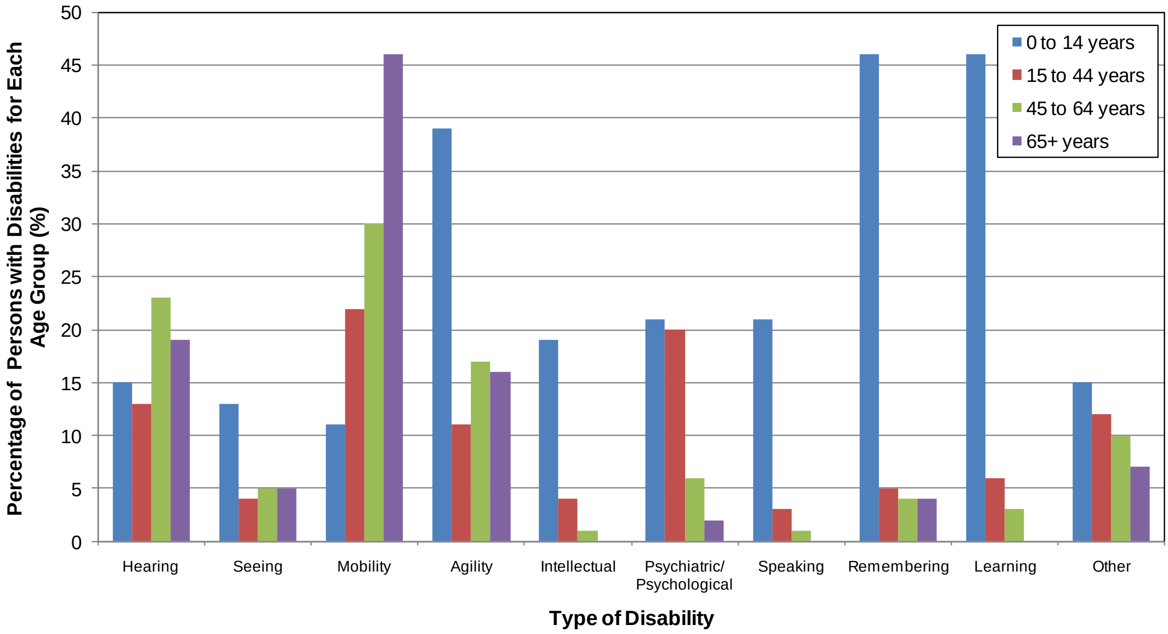

Figure 20: The percentage of type of disability of the people who reported a disability, by age group (SNZ 2010a)

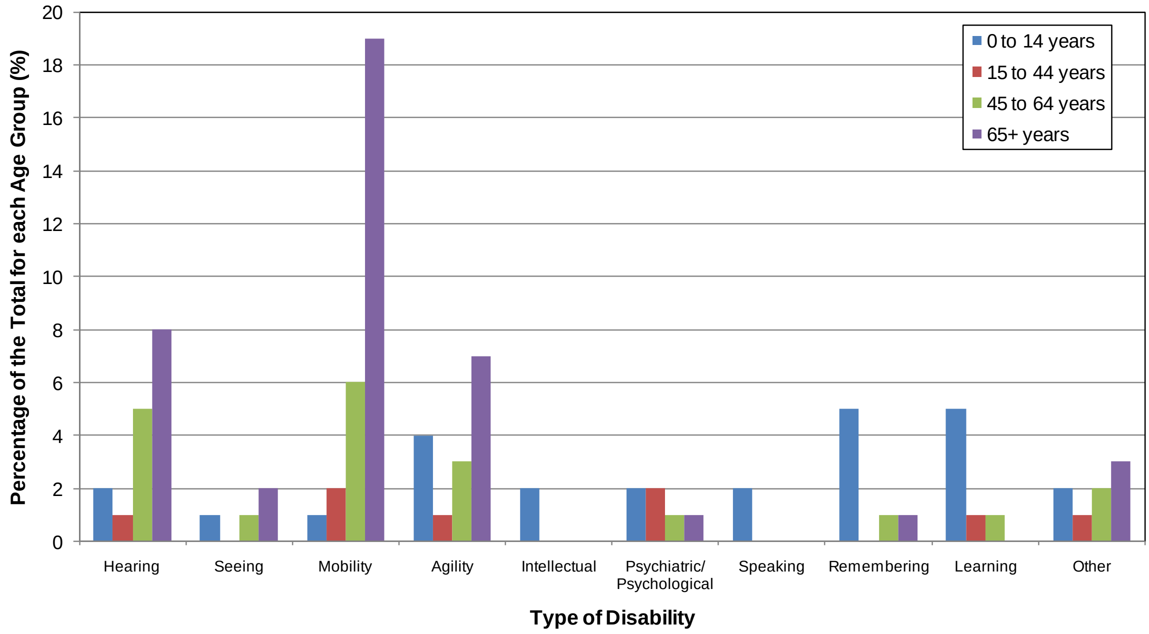

Figure 21: The percentage of each type of disability reported as a percentage of the total population for each age group considered (SNZ 2010a)

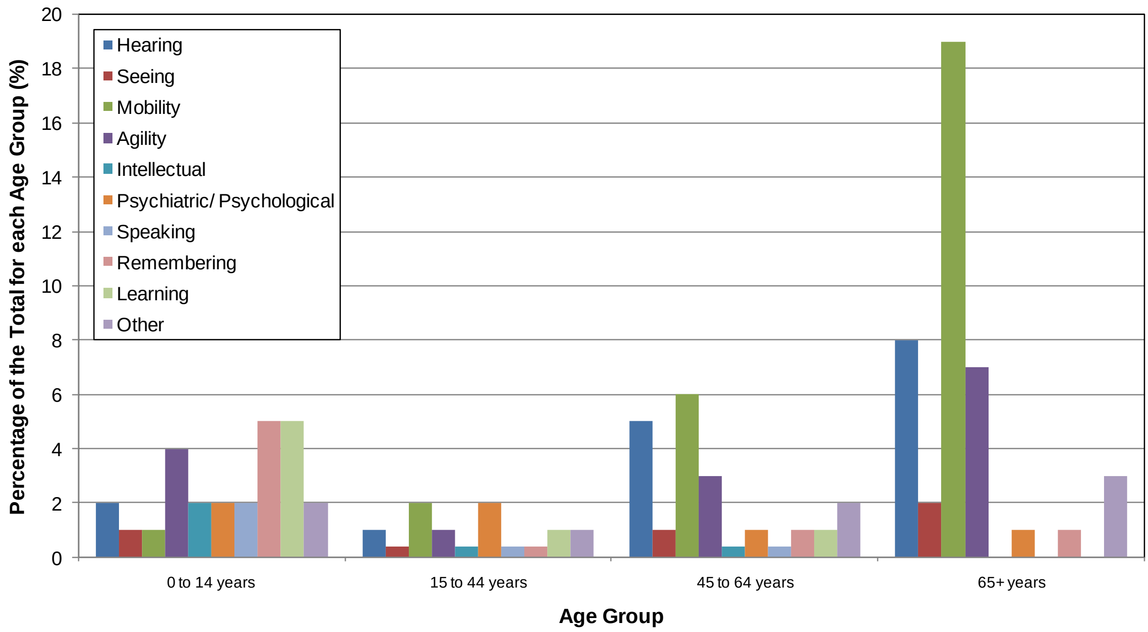

Figure 22: Percentage of reported types of disabilities for each age group considered (SNZ 2010a)

2.3.2.2 Statistics for Residential Care Facilities

Of adults (15+ years) living in residential care facilities, 99.7% reported having a disability. Adults with disabilities living in residential care facilities in the age group 15 to 64 years accounted for 5% of the total adults with disabilities living in residential care facilities. 94% of the adults with disabilities reported multiple types of disabilities. (SNZ 2007)

The number of adults that were in residential care facilities are summarised in Table 24 for each age group. The cause of disability of adults in residential care facilities at the time of the 2006 Disability Survey is included in Table 25. The type of physical disabilities reported by adults in residential care facilities is summarised in Table 26. (SNZ 2007; SNZ 2010b)

Table 24: Age groups of people 15+ years in residential care facilities (SNZ 2007; SNZ 2010b)

Age Group	Number of Adults	Percentage of Disabled Adults in Residential Care Facilities (%)	Percentage of Total Disabled Adults in Age Group (%)	Percentage of Total Adults in Age Group (%)
15-44	-*	-*	-*	-*
45-64	1,500	5	1	<1
65+	29,400	95	13	3
Total	31,100	100	5	7

Table Note:
People may have more than one type of disability.
* Statistical error associated was too large to be reasonably included.

Table 25: Cause of disability for people in the age group of 15+ years in residential care facilities (SNZ 2010b)

Cause of Disability	Number of Adults	Percentage of Disabled Adults in Age Group
Disease or Illness	21,600	69
Existed at Birth	-*	-*
Natural Aging	17,500	56
Accident or Injury	6,100	20
Other Cause	2,900	9
Not Specified	3,100	10

Table Note: People may have more than one cause of disability.

Table 26: Type of disability for people in the age group of 15+ years in residential care facilities (SNZ 2010b)

Type of Disability	Number of Adults	Percentage of Disabled Adults in Age Group
Physical	30,300	97
Sensory	28,700	92
Psychiatric/Psychological	7,400	24
Intellectual	2,100	7
Other	21,700	70

Table Note: People may have more than one type of disability.

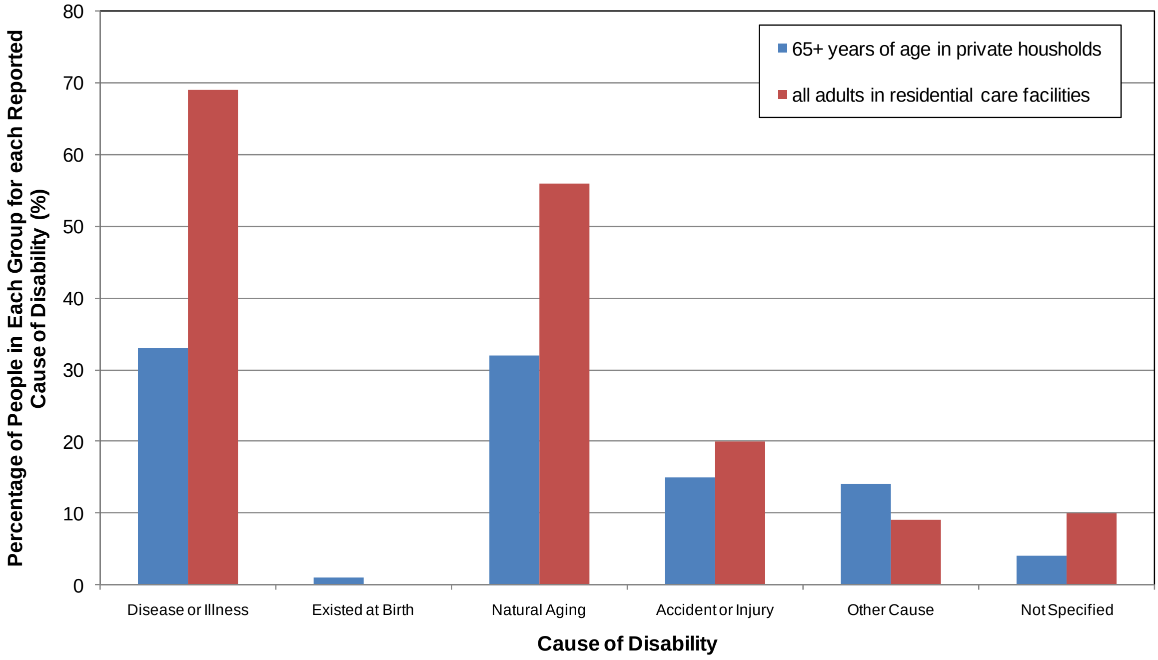

Figure 23: Numbers of people from each type of group (65+ years and living in private households vs all adults living in residential care facilities) considered who reported each cause of disability (SNZ 2010a; SNZ 2010b)

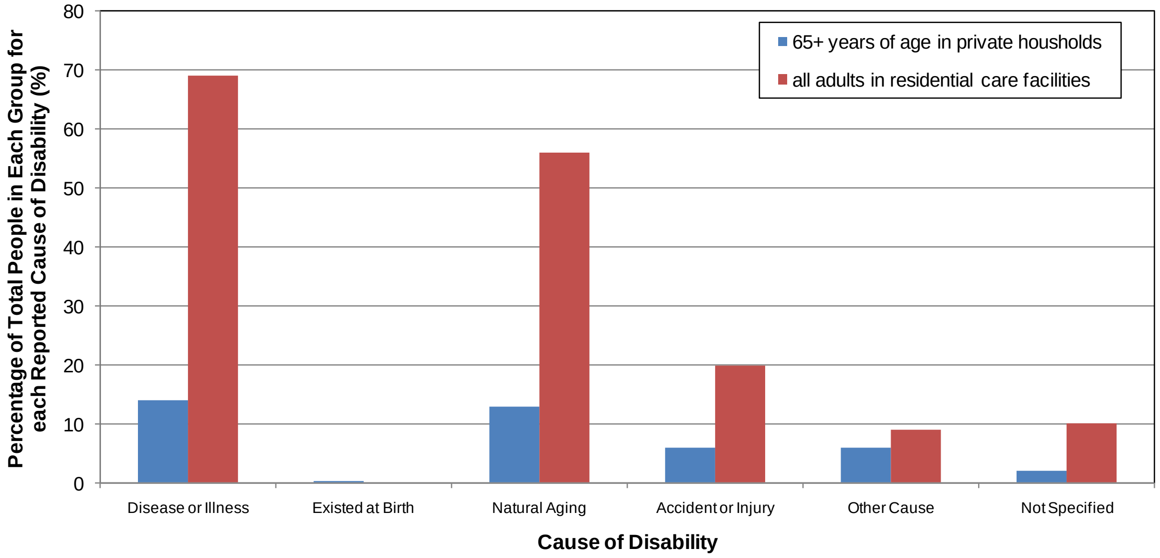

Figure 24: Percentages of each cause of disability reported of the total population (with and without disability) of each group considered (65+ years and living in private households vs all adults living in residential care facilities) (SNZ 2010a; SNZ 2010b)

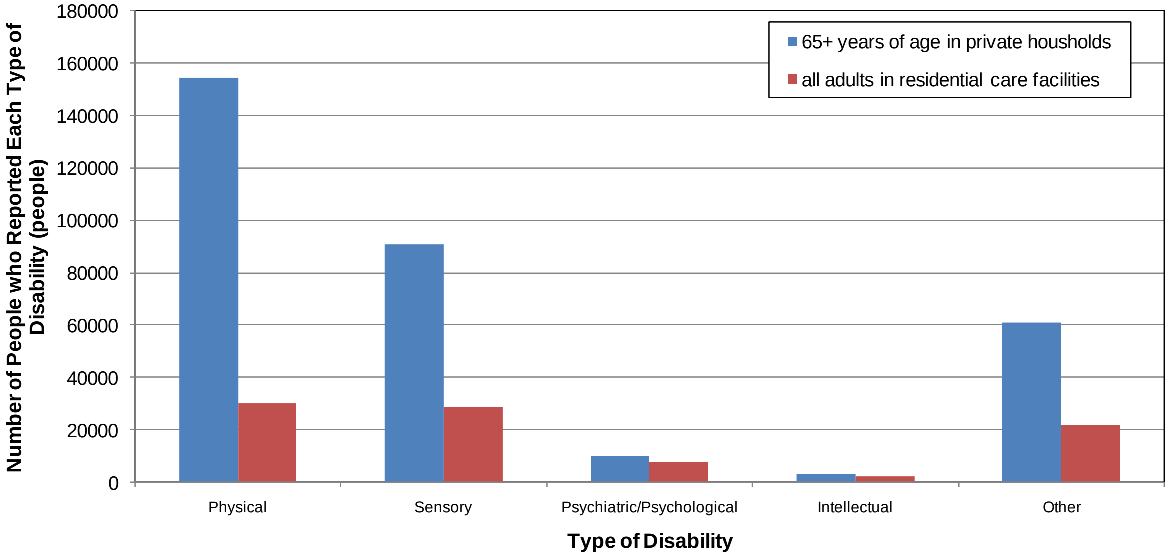

Figure 25: Numbers of people from each type of group (65+ years and living in private households vs all adults living in residential care facilities) considered who reported each type of disability (SNZ 2010a; SNZ 2010b)

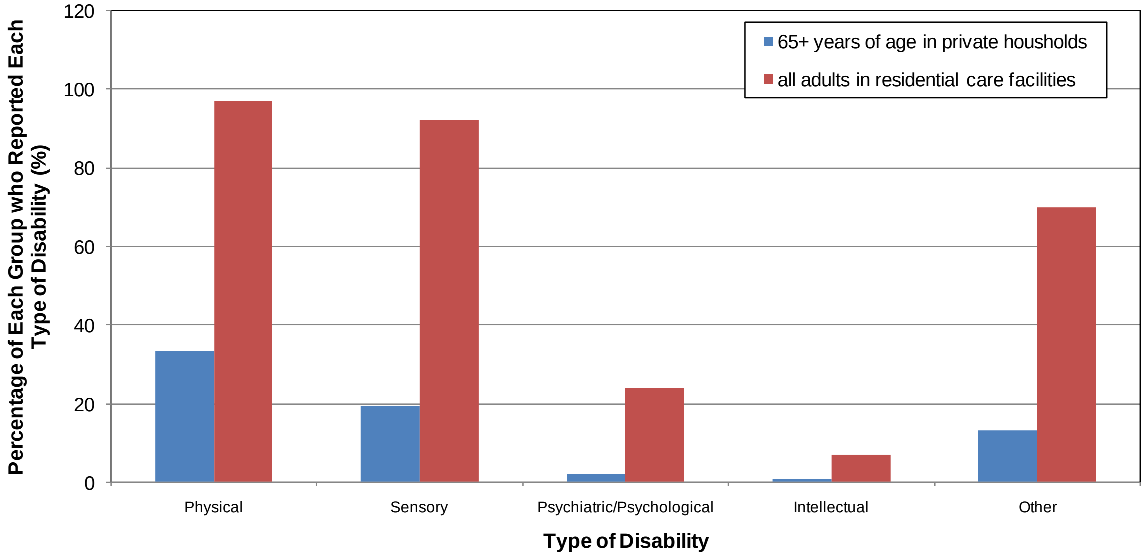

Figure 26: Percentages of each type of disability reported of the total population (with and without disability) of each group considered (65+ years and living in private households vs all adults living in residential care facilities) (SNZ 2010a; SNZ 2010b)

2.4 Describing the General Population versus Sections of the Community

It is important to consider when describing an intended building occupancy as 'general population' that "the line between being 'able-bodied' and being disabled is thin. All people are vulnerable to moderate to severe impairment of mobility, if only temporarily." (Saville-Smith et al. 2007)

In this section the potential descriptions of the 'general population' for a residential occupancy are compared to the sections of the community from which the 'general population' is comprised. Then the 'general population' and the sections of the community are considered in terms of how a residential occupancy is described for use in fire safety design purposes.

From the New Zealand based survey of 121 individuals with disabilities (Saville-Smith et al. 2007), the majority of the participants lived in ordinary houses and ordinary neighbourhoods. Approximately 70% of the survey participants were owner occupiers, which is similar to the rate for the whole of New Zealand. Of the 30% of participants who were renting, the primary type of renting situation was from a private landlord or trust, followed by a tenancy with the Housing New Zealand Corporation. It is important to note that this is a small population, therefore the results are recommended to be only taken in a generally indicative sense.

The majority of survey participants lived in detached single-family single-floor or multiple-floor dwellings, accounting for more than 60% of the respondents. Approximately 10% of the respondents lived in a purpose-built flat. (Saville-Smith et al. 2007)

Furthermore one of the key issues highlighted in the summary report using the data from this survey was that the "accessibility of ordinary homes and neighbourhoods profoundly impacts the independence and productivity of disabled people and their families" (Saville-Smith et al. 2007). Therefore it is not unreasonable to expect a range of disabilities and capabilities of individuals in an occupancy that is expected to represent the general population.

The age at which participants in the New Zealand individual survey (Saville-Smith et al. 2007) first had difficulty undertaking everyday tasks varied from birth to over 65 years or more. Approximately 27% of the participants had lived with their condition since birth, another 15% had experienced difficulties undertaking everyday tasks by the age of 19 years, and there was a relatively even spread of participants for each decade from 20 years onwards.

2.5 Potential Metrics from Non-Fire Safety Related Functionality Measurement Methods

Other methods for assessing aged or otherwise disabled or range of capabilities that are used in the community for health-related or assistance-related evaluation of individuals include:

- Functional independence scales
- Activities of Daily Living
- Functional status assessment or functional assessment of living skills
- Socioeconomic status

- Telemonitoring of people in residential environments
- Disability surveys

These examples of approaches to assessing segments of our community are discussed below in the context of collating information to estimate occupant characteristics.

2.5.1 Activities of Daily Living and Functionality

Activities of Daily Living approaches disability in terms of the inability to perform usual activity of daily living, e.g. bathing, dressing, cooking, cleaning, etc. (Pluijm et al. 2005) Activities can be divided into:

- Personal care (including functional mobility and transfers, and personal grooming, etc.),
- Domestic activities, and
- Community activities.

There have been a range of aging studies based on the framework of Activities of Daily Living (Ball et al. 2004; Pluijm et al. 2005). There are several approaches to applying this framework, however the Katz Index is one of the most commonly applied. The Katz Index of Independence in Activities of daily living is based on several aspects of usual daily activities (Katz et al. 1963):

- Bathing,
- Dressing,
- Transfers (getting into and out of bed, sitting and standing from a chair),
- Toiletting,
- Eating,
- Walking in the home, etc.

Participants of the surveys are asked questions to ascertain how much assistance they require to perform each of the activities. The response is categorised into levels of assistance required. (Katz et al. 1963; Pluijm et al. 2005)

Such a rating system may be useful for determining when an individual needs to be transferred between levels of in-home care and/or institutional levels of care, or to provide a snap-shot of a population. However, in relation to fire safety design, the qualitative nature of the scale means that the results would only be generally indicative of the high-level description of the type of purpose group or occupancy type rather than provide insight as to the quantitative range of capabilities and limitations.

It is also important how performance can deteriorate with increasing age. (Formiga et al. 2010)

Functional independence, or ability, scales provide a measurement of function living skills using common activities, in a similar approach to the Activities of Daily Life scales. However a more quantitative measurement approach may be applied using the Functional Independence Scales. One common application of these scales is to estimate the impact of medications on the lives and functionality of patients. (Gray et al. 2006; Moore et al. 2007)

Similar metrics, as used in the Activities of Daily Life approach (Katz et al. 1963; Pluijm et al. 2005), are collated, such as (Moore et al. 2007):

- Grooming or hygiene,
- Dressing,
- Eating,
- Time,
- Safety,
- Communication,
- Financial skills,
- Cooking or meal preparation,
- Shopping,
- Transportation,
- Medication management,
- Leisure,
- Chores, etc.

These types of approaches can be more detailed than the Activities of Daily Life approach, and are more commonly applied to individuals that are more active and are less near to the border of needing full-time care or assistance or institutionalisation. Therefore a database for older adults based on such an approach may be useful in estimating the ranges of capabilities and limitations associated with the older age group. However care must be taken when including results from other surveys the intent of the initial survey must be taken into account. For example a set of results based solely on medicated individuals, or other specific groups that another study might be interested in would produce biased results that would not be useful unless the intended building occupancy directly pertained to the focus of the study.

Methods for assessment of executive functions in adults with intellectual disabilities include the adaptation of a Tower of London planning and problem solving test (Masson, Dagnan and Evans 2010). For this assessment method, individuals completed the Tower of London test, while carers completed questionnaires related to the adaptive function of the individuals (using an Adaptive Behaviour Scale – Residential and Community test, Second Edition, modified version, and DEX-Independent Rater). The results from the tests that were applied to the individuals were compared to the results from the questionnaires completed by carers. The results from the comparison lead to suggestions that the adapted Tower of London test was useful for characterizing people with intellectual disabilities, however it was recommended that it not be used along and instead be used in conjunction with assessments tools for everyday planning tasks to provide a more complete picture of the capabilities of the individuals.

Cognitive and functional performance (assessed with ADL and face to face interviews) of older adults have also been compared to other metrics, such as albumin, haemoglobin, body mass index, physical mobility, life expectancy and extrapyramidal signs (i.e. related to motor control for coordination of movement that can be demonstrated by the inability to initiate movement or to remain motionless, etc.). (Bell-

McGinty et al. 2002; Desrosiers et al. 2003; Kono et al. 2004; Oxley et al. 2005; van Hooren et al. 2005; Bennett et al. 2006; Gill et al. 2006; Yeom, Fleury and Keller 2008; Onem et al. 2010)

For example, the correlations were positive between the functional assessment results and the biochemical results, except for serum sodium, were positive. There were also positive correlations between cognitive function and haemoglobin, body weight and ADL results. Negative correlations were reported between ADL assessments and both serum sodium and age, as well as between cognitive function and serum sodium. It was suggested that improvement of haemoglobin and albumin levels in an elderly population could improve cognitive and physical functional status. Although a fire-safety designer would not have influence over the medical state of the intended occupants, conversely it may be useful to understand the biochemical thresholds that are used by the healthcare industry to determine different levels of care and how these thresholds may influence expected ranges of cognitive and physical function. (Onem et al. 2010)

2.5.2 Residential Telemonitoring of Elderly

The intent of the use of residential telemonitoring systems for the elderly is to facilitate the prevention early diagnosis and management of chronic medical conditions. (NiScanaill et al. 2006; Bamis et al. 2010; Dadlani et al. 2010; Wang et al. 2010; Xefteris et al. 2010) One application of the technology was suggested as the long-term application of the approach to help detect gradual decline in an individual’s health status.

Mobility was the key metric monitored and recorded, to assess the health status of elderly persons living independently in their own homes. There are various monitoring systems, including smart homes, wearable and combination systems. The systems range from detecting the location of the subject and therefore indirectly estimating the mobility of the individual or may also have biomedical parameters. With advances in technology, these systems are becoming lower cost and less obtrusive for the individual and therefore are becoming more widely introduced for elderly and chronic patients. (NiScanaill et al. 2006)

The introduction of this type of technology into home and community locations is supported by multiple organisations, including the Veterans Health Administration and Kaiser Permanente in the US. There may be future opportunities to work with such organisations with the introduction and use of similar useful technologies throughout homes and communities in New Zealand.

As this type of system and systems similar to this become more widely used, the spread of data may be useful, in the context of fire safety design, for estimating the range of mobility levels in elderly who reside independently in their own home.

2.5.3 Socioeconomic Status

Socioeconomic status is commonly used to assist in identifying high fire-related risk segments of our community, e.g. Jennings (1999), University of Otago (2000), Duncanson, Woodward and Reid (2002), Mulvaney et al. (2008), Bell, Schurman and Hameed (2009), Corcoran, Higgs and Higginson (2010), Rohde, Corcoran and Chhetri (2010) etc. However the metrics are not directly useful for estimating those associated with occupant characteristics for fire safety design of buildings.

2.5.4 New Zealand Disability Survey

Some of the metrics reported on, as part of the New Zealand based survey of individuals with disabilities (Saville-Smith et al. 2007), included:

- Walking 300 m;
- Walking up and down stairs;
- Carrying a 5kg mass over a 10 m distance;
- Moving from one room to another;
- Standing for 20 min;
- Moving around the house without assistance or modification to the house;
- Moving around their local town or city without assistance.

Of these metrics, ‘moving from one room to another’, ‘moving around the house without assistance or modification to the house’ and ‘moving around their local town or city without assistance’ would have an interdependence between the abilities of the individual and the design of the accessibility of the relevant buildings and the neighbourhood. Therefore these metrics would not be useful for describing an occupancy, instead they could be used as a measure of the accessibility of a building or neighbourhood when compared to the capabilities of the individual.

The values reported for these metrics were self-estimates of the level (low, moderate or high) of support needs of the individual. The qualitative nature of the results does not directly assist with estimating characteristics of an occupancy in a fire safety design context.

2.5.5 Estimation of Time

Estimation of time has been shown to change with age as well as gender. (Espinosa-Fernandez et al. 2003) This may have implications related to how long an individual estimates they have to escape, in addition to reporting of the timing for post-emergency case studies.

2.5.6 Auditory Comprehension

Differences in the comprehension ability of auditory commands have been reported to change with age. (Alain and Snyder 2008; Szymaszek, Szelag and Sliwowska 2006; Hancock and Rausch 2010) Difficulties reported to increase with age of the participants included hearing amplitude as well as depicting vowels in speech. The time to respond to an auditory stimulus also increased with age. Therefore the ability to interpret and respond appropriately to a series of commands may change over time, and practiced responses to potential emergency situations may become more important with increased age of the occupants. These considerations may be included in selection of appropriate notification methods and messages.

2.5.7 Pain Tolerance

Reduced pain tolerance in older adults compared with younger test subjects has been reported based on experiment results. (Cole et al. 2010) Older adults were also reported to have more complains of chronic pain than young adults. The type of pain administered during the tests reported by Cole et al. (2010) involved applied pressure. Differences were also reported between older adults living independently at home and those living in care facilities. (Jakobsson, Hallberg and Westergren 2004) Responses to heat, temperature or irritant smoke were not considered in these tests; however these types of aspects might be considered in the selection of tenability criteria when evaluating designs intended for older occupancies.

2.5.8 Summary of Non-Fire Safety Metrics

Although results from surveys and censuses that are not directly related to fire safety, useful insights arise from other fields that are associated with the description and characterisation of individuals or parts of the community that comprise the intended building occupancies of interest. Therefore there may not be currently available information that can be directly used to collate data for use in fire-safety design and assessment of buildings, however there may be future opportunities to work more closely with organisations that issue and conduct surveys and assessment methods of ranges of capabilities or limitations of individuals such that useful information can be collated from these potential sources.

Closer ties with other organisations may also assist in standardising ranges of functionality of type of occupancies with thresholds recommended for different levels of care or service.

2.6 Considerations of Multiple Impacts on the General Residential Population

The effect of multiple hazardous impacts on the effectiveness of a building design is rarely considered. Such considerations of multiple hazardous events occurring in series or parallel may be rare due to a low likelihood. For example, the occurrence of a fire event after an earthquake is not a typical design fire scenario used to challenge a building design. Even though the likelihood may be very low, the consequence may be very high, therefore such events need to be considered and ranked appropriately in relation to all other applicable scenarios.

Similarly, additional events (either serial or parallel) to a fire event that may impact the behaviour or capabilities of an intended building population should also be considered in terms of likelihood and consequence. For example, such additional events may include a residential population being temporarily influenced by a localized outbreak of a contagion. The impact on the characteristics of an intended occupancy may include the influence of the medical symptoms and medication on the awareness, response and capabilities of the occupants to escape. In addition, there may be a reluctance to interact with other occupants or share the same spaces. This may influence the consideration of staying in place instead of evacuation that would otherwise not be the case.

3. SUMMARY OF THE CURRENT PRACTICE AND GUIDANCE FOR EGRESS DESIGN

3.1 General

Building designs for occupancies that are considered either long-term or temporarily used by disabled persons tend to be such types of buildings as nursing homes or hospitals. The strategies for providing fire protection to the occupants of these types of buildings typically consist of a combination of building design, staff training and the ability to protect occupants in place until evacuation can be carried out.

However for buildings that are considered to have an occupancy that can be described as typical of the 'general population', the proportion of long-term or temporarily disabled persons (or persons with a range of capabilities less than ideal) is assumed to be small, if not negligible. Furthermore it is assumed that during an evacuation there will be persons capable, willing and available to assist any persons with long-term or temporarily reduced capabilities to escape. As the proportion of an occupancy with reduced capacity for self-evacuation from a building (being dependent on both the specific building design and capabilities of the individuals at the time of evacuation) increases, reliance on the assistance of other occupants becomes unfeasible.

The following sections consider aspects of building design fire safety concepts in terms of the potential capabilities of intended occupants.

3.2 Individual Evaluation of Situation

An individual uses several processes to evaluate a situation, such as the threat of a fire incident. These processes have been described as (NFPA 2008):

1. Recognition
   - Perception of the cues of the threat of fire. This is the initial awareness of a possible threat. These cues may be ambiguous.
     - Sensory perception
2. Validation
   - Determine the seriousness of the cues. This usually is to seek reassurance of the mild nature of the threat and the improbability of the threat.
     - Information seeking
3. Definition
   - Describe the magnitude and time urgency of the threat.
     - Context of information
4. Evaluation
   - Decision of whether or not to respond and what type of behavioural response to make, such as a fight or flight response.
     - Cognitive and psychological activities leading to decision making
5. Commitment

- Implementation of the decided plan in response to the threat
    - Mobility, memory, cognitive, oral.

6. Reassessment

- Failure of the implementation of the plan to remove the threat, therefore the process is reiterated until successful
    - Sensory and cognitive to identify the ineffectiveness of the plan and to initiate the process again

Any reduction in the sensory or cognitive capabilities of an individual may delay or break this process, resulting in a delayed time to the start of a response to the threat or unexpected response to the perceived threat or no response at all to the threat.

3.3 Alarms and Notification

3.3.1 Awareness of a Fire Incident

The following table is a summary of a British and three USA studies conducted to identify the initial means of awareness of individuals to a fire incident in residential occupancies. (NFPA 2008; SFPE 2008) The participants of the studies were of a range of ages and abilities, therefore this list is only presented to provide a general indication of the methods by which individuals become initially aware of a fire event. Two major influences must be taken into account when considering these data sets. Firstly the study participants are those who have survived a fire incident and secondly the fire safety features of the building in which they would be a dominant influence (e.g. if the evacuation plan relied on personal notification of the occupants by other occupants, or the type of alarm system that was present and the effectiveness for the specific situation). Therefore the results of these studies are only used as a general indication of the types of cues reported by individuals and may be more useful as an indication of what cues individuals either accepted or used as notification of the emergency.

'Hearing an alarm' consistently featured a low percentage of reports as being the initial means of awareness of a fire incident, whereas 'being told or hearing shouts' consistently featured highly. Smelling, seeing or hearing other noises associated with a fire incident relies on the perception and recognition of the individual of possibly ambiguous cues. Therefore an intelligent use of a human voice alarm might be designed as a combination of these two means of alerting, informing and directing the occupants of a building. (SFPE 2008) The message would need to be tailored to the intended occupants and the specific building.

For an alarm to be as effective as possible, it was suggested that the sound intensity at the pillow should have the highest chance of arousing the most at risk of fire deaths, which include the elderly. 90 dBA was suggested for smoke alarms installed in bedrooms. (CPSC 2004) The signal level, of which the amplitude is only one measure, and the type of sound or signal have been reported to affect the probability of awakening a sleeping subject. (Bruck and Thomas 2009; Thomas and Bruck 2010) Awakening is discussed in more detail in the following section.

Another consideration, if individual assessment of residences are performed, is whether or not individuals are wearing hearing aids at the time of the assessment and whether there is a difference in response to the alarm when the individual is wearing or not wearing (e.g. turned off or taken out) the aid. Therefore multiple signal types might be useful to notify the resident without being debilitating or ignorable.

Table 27: Initial means of awareness of a fire incident in a residential occupancy from studies conducted in Britain and the United States. (NFPA 2008; SFPE 2008)

Initial Means of Awareness of a Fire Incident	Percentage of Participants from Each Study			
	British Study [a]	United States of America		
		Study A [b]	Study B [c] Occupant in Fire Room	Study B [c] Occupant Not in Fire Room
Saw Flame	15	7	23	6
Smelled Smoke	34	35	12	9
Heard Noises	9	11	15	12
Heard Shouts or Was Told	33	35	12	35
Heard Alarm	7	7	8	8
Other	2	3	31	30

Table Notes:
[a] From a study reported in Wood (1972). Total of 2193 participants.
[b] From a study reported in Bryan (1977). Total of 569 participants.
[b] From a study reported in Purser and Kuipers (2004). Total of 26 participant of occupants in the fire room. Total of 93 participants of occupant not in the fire room.

Considering emergency voice notification systems, in research focused on optimising fire alarm notification of high risk groups, Gwynne (2007) listed the aging population as being a vulnerable population for having difficulties perceiving, paying attention to and/or comprehending a fire notification warning. Other functional conditions that may also make the intended occupancy vulnerable included sensory disability (such as hearing impairments or loss and vision impairments or loss) of individuals, cognitive disabilities (including thinking and learning disabilities) of individuals, children, large groups, isolated people, sleeping people, intoxicated or sleep-deprived people, non-native speakers, untrained or un-primed people, and people who are committed to an activity before the warning begins. This list may additionally apply to the aging people group, further complicating the functionality of individuals. Therefore care must be paid to the content, style and frequency of the message (Mileti and Sorensen 1990) intended to inform the building occupants of the situation and provide instructions. In addition, other evacuation systems and procedures should also account for such functional limitations of the intended building occupants.

Furthermore, stress and anxiety experienced as a reaction to an emergency situation has been shown to reduce an individual's capacity to pay attention and process information. (Kesselman, Slaughter and Patel 2005; Chandler 2010) On the other hand, individuals in a familiar environment may overlook new information and messages, responding to the situation based previously learned habits and conditioning. (Chandler 2010) There have also been accounts of elderly people responding to an alarm sounding with panicked dispersion and having to be located individually. (Fahy, Proulx and Aaiman 2009) Therefore a diverse range of behaviour may be expected in response to an alarm.

3.3.2 Awakening

Sleeping has a strong influence in the likelihood of the occurrence of fire casualties and fatalities (Hasofer and Thomas 2006), therefore the methods for potentially awakening occupants is of high concern for residential designs.

A study of the smoke detector noise levels indicated that a level exceeding 100 dB may be required when individuals have hearing impairments, are affected by sleeping pills, or are on medication. (Berry 1978; NFPA 2008) Furthermore, a study investigating the auditory arousal thresholds of sleeping individuals reported more frequent awakenings in response to lower stimulus intensity as age of the individual increased. It was also reported that individual differences accounted for more variability of the recorded thresholds than sleep stage or age. (Ball and Bruck 2004; NFPA 2008; Bruck 2001) Therefore although age of the intended occupants may be a consideration, other attributes of the individuals may be more important in determining the most effective alarm for awakening intended occupants.

Another consideration is that an alarm may be attenuated by the surroundings (such as a reduction of up to 40 dB when passing through a ceiling or wall, a reduction of up to 15 dB when passing through a door) or an alarm may also be masked by other noises (such as an air conditioning unit, typically of the order of 55 dB). (Nober et al. 1982; NFPA 2008) If such considerations were to be taken into account in excess of the minimum suggestion of 100 dB for hearing impaired or medicated individuals, then it would be worth considering the threshold where by the noise level becomes debilitating or counterproductive for escape of the individual.

For older adults without hearing impairments, it was reported by Bruck and Thomas (2008) that the most effective signal for waking sleeping experiment participants was a mixed frequency T-3 signal (500 to 2500 Hz). Furthermore the median auditory arousal threshold for the mixed frequency signal was 20 dB lower than the mean required when the high pitched T-3 signal was used.

It has been suggested that effective fire signals in occupancies with hearing-impaired persons include flashing or activated lights. (Cohen 1982; NFPA 2008)

3.3.3 Ambiguous Fire Incident Cues

Ambiguous cues to alert an individual of a fire incident will extend the time to recognise the situation. This leads to a delayed evacuation that may lead to a lessening of available time and increased stress on the individual. Lessening of the available time for escape may lead to non-adaptive flight behaviours and inhibition of assistance behaviour. Furthermore, it has been reported that it can be difficult to get occupants to self-evacuate from a building because of social inhibition and diffused responsibility. (NFPA 2008)

3.4 Choice of Exit

When considering residential buildings, it is assumed that the occupants will be familiar with their surrounds. However occupants are likely to choose the exit they most regularly use, even though there may be closer or safer means of egress. (Proulx 2009) Also it has previously been noted from case studies that older adults are less likely to make use of alternative exits, such as windows (Brennan 1998).

3.5 Convergence Clusters

Convergence clusters were first reported for a high-rise apartment fire in 1979. It is suggested that the clusters involve occupants converging in specific rooms they perceived as areas of refuge. (NFPA 2008)

There is insufficient data available to conclude what types of occupant attributes may be used to indicate a tendency to this type of behaviour. Convergence clusters may need to be considered during evacuation planning.

3.6 Assistance Behaviour

Assistance behaviour is the altruistic response of able-bodied occupants to help facilitate in the escape of other occupants that are not as able-bodied.

Assistance behaviour has been reported in post-emergency case studies (NFPA 2008), where disabled occupants had successfully escaped with the assistance of other occupants that they may or may not have been acquainted.

It has been questioned as to how to appropriately handle modelling of emergency egress with altruistic assistance behaviour. (Pan, X. et al. 2006)

There is insufficient data available to assess the reliability of assistance behaviour in the successful escape of disabled persons. For example, in order to assess the extent of assistance behaviour during an emergency evacuation and whether persons with disabilities have escaped predominantly because of altruistic actions of others, it would be useful to compare data sets for:

- successful escape of occupants with disabilities with assistance of other occupants,
- successful escape of occupants with disabilities without assistance of other occupants,
- occupants with disabilities who did not successfully escape, although they did have other occupant(s) assisting them, and
- occupants with disabilities who did not successfully escape and did not have assistance of other occupants (e.g. Thomas, Bruck and Barnett (2009)).

It would also be useful, in terms of improving design for evacuation, to compile the reasons or situations where occupants with disabilities could not self-rescue.

In addition, as it has been previously suggested, shortening of available time for escape may lead to non-adaptive flight behaviours and inhibition of assistance behaviour. (NFPA 2008)

Therefore it is unreasonable to rely on the ideal, altruistic assistance behaviour of an occupancy as part of a evacuation scheme or plan. Where the intended occupancy of a building includes a range of capabilities of individuals, then it is necessary to design for the self-evacuation of the full range of the intended occupancy.

3.7 Occupant Fire Fighting

The most commonly reported reason for not evacuating a building during a fire event was to participate in fire fighting efforts. (NFPA 2008; SFPE 2008) Occupant fire fighting behaviour has been reported for individuals from at least 7 to 80 years of age. A sample of 134 study participants who had demonstrated fire fighting behaviour during fire events was summarised. (NFPA 2008; SFPE 2008) However the percentage of each age group participating in fire fighting behaviour was not compared to the number of occupants in the building(s). Therefore there is currently insufficient information to indicate whether or not there is a tendency with increasing or decreasing age to engage in fire fighting behaviour.

Another consideration is that it has been suggested that older adults may have minor cognitive and physical impairments that may impede successful use of fire fighting equipment. (Bruck and Thomas 2010)

3.8 Re-Entry Behaviour

Re-entry behaviour is the term that describes an occupant that has successfully escaped the building but then chooses to re-enter the building. Re-entry behaviour is typically undertaken in a deliberate, purposeful manner, without anxiety or self-doubt. This behaviour can hinder the efficient and effective evacuation of other occupants by using a means of escape to re-enter the building. The reported reasons for re-entry range from fighting the fire, retrieving personal property, checking on the fire, notifying others, assisting the fire department and retrieving pets, turning off appliances or gas, etc. A commonly reported reason for re-entry by individuals in studies conducted in the USA and Britain was to 'save personal effects'. (NFPA 2008; SFPE 2008)

Re-entry behaviour in terms of the relation to occupant age may be a consideration for another parameter of interest.

3.9 General Modelling Considerations for Occupancies including Persons with Disabilities

Using modelling approaches, walking speed, such as walking upward on stairs, has been found to be a key parameter with a significant influence on the estimated evacuation time (e.g. Jiang, Yuan and Chow 2010). Therefore it is not only important to use parameter ranges that appropriately characterise the occupancy type of interest, but also utilise sensitivity analyses to identify all the key parameters influencing the modelled results.

Considering the differences in the capabilities of people with disabilities, the range of aids (e.g. mobility aids, etc.) that may or may not be used by individuals and the inherent requirements (e.g. spatial, visual, etc.) for each combination, it is suggested that when applying evacuation modelling approaches that the different environmental requirements be considered separately. (NFPA 2008)

When modelling the evacuation of people with a range of capabilities, it may be necessary to include fatigue, periods of rest and additional time required to make changes in escape direction. (NFPA 2008)

3.10 Designing Buildings for Persons with Disabilities

Design of buildings to facilitate access for people with disabilities during normal activities is fundamentally different to design of accessible emergency escape. However the design of accessibility for normal activities is common design practice (e.g. it is included in prescriptive solutions such as D1/AS1 (DBH 2001)), whereby ensuring people with disabilities have safe access into and out of a building during non-emergency situations. Whereas the accessible emergency escape routes are not typically included in prescriptive solutions (e.g. an escape route is only required to be accessible if it coincides with an accessible route by C/AS1 (DBH 2010)), therefore people with disabilities may gain access to a building via an accessible route but may have to use a non-accessible escape route during an emergency evacuation.

Examples of changes in non-emergency building design for access for people with disabilities may include:

- Ramps instead of stairs
- Lift access
- More handrailings
- Easier to use door hardware or powered door openers (e.g. switch or automatic operation)
- Wider doorways and corridors
- Clear signage to locate available routes and facilities

Another consideration is the ease of use or ergonomics of aspects of building designs intended for ‘person with disabilities’ for persons without disabilities. In addition, identify where conflicts in aspects of building designs might occur for different types of disabilities.

Design solutions for accessible routes may not directly translate to accessible escape routes. For example, when considering the differences between normal building access, or even non-emergency pre-advertised evacuation drills, and emergency evacuation include (NFPA 2008):

- Perception of imminent damage to self or others
- Visibility of evacuation path due to smoke, loss of lighting or other event
- Blockage of escape routes due to heat, debris or other event (e.g. a fall of an evacuating occupant)
- Full participation by all occupants
- Knowledge that the building may not be reoccupied may encourage additional gathering of items (e.g. keys, purses, computers, phones, jackets, etc.)

Therefore accessibility must be considered in the building design in the context in which it is intended for use, i.e. an accessible route is not an accessible escape route.

3.11 Adaptation of Other Fire Safety Solutions

Fire safety solutions currently developed or used for other situations may be adaptable to building designs intended for people with disabilities. One example of current evacuation technology that may possibly be designed for evacuation of people with disabilities is protected elevator evacuation that has been suggested as an alternative to walking many flights of stairs, especially for tall buildings (Tubbs & Meacham, 2009).

3.12 Fire Safety Features and Human Interaction

Interaction between fire safety features and the individuals in a building have a large influence on the effectiveness of providing life safety of the building occupants. (Kobes et al. 2010) A summary of the types of human interaction between potential fire safety features and individuals is presented in Table 29. Descriptions of the terms used for the types of human interaction are included in Table 28.

Table 28: Description of types of human interaction used in Table 29

Type of Human Interaction	Brief Description
Mobility	speed and obstacle negotiation
Olfactory	sense of smell
Sensory	combined senses of odor, temperature (touch), visual and auditory cues.
Constitution	endurance, and discomfort and pain physical and mental response
Cognitive	correct interpretation of the situation and intention of response
Memory	correct recall of expected response, current location in building and exitways, etc.
Strength	ability to push and pull an object (e.g. a door, etc.)
Manual dexterity	ability to operate a device with the hands (e.g. operate a door lever, turn on a faucet, dial a phone number, operate a wall switch, etc.)
Visual	ability to correctly detect and interpret a visual cue
Auditory	ability to correctly detect and interpret an auditory cue
Oral	ability to communicate verbally

Table 29: Summary of fire safety features and human interaction

Type of Fire Safety Feature	Fire Safety Feature	Human Interaction
Detection	Human detection (other residential occupants or staff)	Olfactory Visual Auditory Cognitive
	Automatic detection	Intentional or inadvertent interaction may delay, disarm or falsely activate the device or system component
Notification	Smoke alarm	Auditory Cognitive
	Emergency notification system	Auditory Cognitive
	Human notification (other residential occupants or staff)	Oral Auditory Cognitive
Exitway	Signage	Visual Cognitive
	Doors	Mobility Strength Manual dexterity
	Stairs	Mobility Constitution
	Distance	Mobility Constitution
Passive Fire Protection	Smoke doors	Mobility Strength Manual dexterity Sensory (e.g. safe to open) Cognitive (e.g. safe to open, obstruction of closing action, etc.)
	Fire doors	Mobility Strength Manual dexterity Sensory (e.g. safe to open) Cognitive (e.g. safe to open, obstruction of closing action, etc.)
	Separation by distance from non-fire rated construction (e.g. from an un-insulated glass window, etc.)	Cognitive Sensory Constitution
	Natural cross-ventilation (e.g. open-air balconies or stairways, etc.)	Cognitive Sensory Constitution
	Separation by fire-rated construction (not part of occupant thoroughfare)	Intentional or inadvertent interaction may decrease the fire rating of a component of the separation (e.g. putting holes in firewalls, or hanging a heavy tapestry on a firewall, etc.)
Active Fire Protection	Fire sprinklers	Intentional or inadvertent interaction may delay, disarm or falsely activate the device or system component
	Hold-open devices	Intentional or inadvertent interaction may delay, disarm or falsely activate the device or system component
Emergency Evacuation Plan	Evacuation plan execution by individual	Cognitive Memory
	Evacuation assistance by staff	Cognitive (e.g. resistance to help from staff by individual, likelihood of attempted re-entry to the building after evacuation, etc.) Mobility (i.e. in terms of how much assistance is required)
Fire Fighter Operations	Fire fighter rescue operations	Cognitive (e.g. resistance to help from staff by individual, likelihood of attempted re-entry to the building after evacuation, etc.) Mobility (i.e. in terms of how much assistance is required)
	Fire fighter suppression operations	Intentional or inadvertent interaction may delay fire fighter operations

4. NEW ZEALAND PRESCRIPTIVE REQUIREMENTS

Considering the Compliance Documents associated with fire safety, C/AS1 (DBH 2010), the level of capabilities of the occupant groups used in the prescriptive solution is not explicitly described. However there are references to the general segment of our community described by 'people with disabilities' in isolated areas of the document.

The follow are brief summaries and discussions of parts of the New Zealand prescriptive solution for fire safety (C/AS1 (DBH 2010) where reduced levels of capabilities of the intended purpose groups for residential occupancies (SH relating to detached dwellings, SR relating to multi-unit residential dwellings, SA relating to transient sleeping accommodation such as a hotel, etc.) are included in consideration of requirements. (For this study, healthcare facilities such as SC and SD were outside of the scope of the report.)

There are no fire safety related requirements for SH associated with specified levels or capability or disability of the intended occupants. (C/AS1 (DBH 2010))

4.1 Select Definitions

The following are definitions of terms used in the prescriptive solution, C/AS1 (DBH 2010), associated with levels of capability or disability of the intended occupants.

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 physical, sensory, neurological, or intellectual impairment*
- *a mental illness*." (Definitions, C/AS1 (DBH 2010))

Physical, sensory and cognitive abilities may degenerate with age or may be influenced by medical conditions (e.g. cardiac disease, respiratory disease, pregnancy, etc.) and the decrease in functionality may be transient (e.g. in the cases of a recoverable injury or illness) or long-term.

Access routes are only required to be provided for people with disabilities for specific buildings, according to the objective of Clause D1 – Access Routes of the New Zealand Building Regulations (1992). These buildings include those intended for public use, industrial buildings with more than 10 employees and other types as described below.

Housing is explicitly excluded from requiring access routes. (D.1.3.2, Building Regulations 1992) Housing is defined as (Building Regulations 1992):

- applying to "*buildings or use where there is self care and service (internal management)*", of which there are three types:
    - detached dwellings:
        - "*a building or use where a group of people live as a single household or family*",
        - e.g. "*holiday cottage, boarding house accommodating less than 6 people, dwelling or hut*".

  - Multi-unit dwelling:
    - "*a building or use which contains more than one separate household or family*",
    - e.g. "*an attached dwelling, flat or multi-unit apartment*".
  - Group dwelling:
    - "*a building or use where groups of people live as one large extended family*",
    - e.g. "*commune or marae*".

However residential types of building other than '*housing*' are required to have an access route for persons with disabilities. These types of residential buildings are termed 'communal residential' and are defined as:

- applying to "*buildings or use where assistance or care is extended to the principal users*", of which there are two types:
  - Community service:
    - "*a residential building or use where limited assistance or care is extended to the principal users*"
    - e.g. "*a boarding house, hall or residence, holiday cabin, backcountry hut, hostel, hotel, motel, nurse's home, retirement village, time-share accommodation, a work camp or camping ground*".
  - Community care:
    - "*a residential building or use where a large degree of assistance or care is extended to the principal users" of which there are two types*:
      - "*Unrestrained, where the principal users are free to come and go. E.g. a hospital, old people's home or health camp*", and
      - "*Restrained, where the principal users are legally or physically constrained in their movements. E.g. a drug rehabilitation centre, an old people's home where substantial care is extended, a prison or hospital*". (Building Regulations 1992)

Therefore, considering the focus of residential building for this study, if any service or care is provided to the residents of the building, then accessibility must be provided to "*ensure that people with disabilities are able to enter and carry out normal activities and functions within buildings*". (D.1.1.c, Building Regulations 1992)

Other terminology used in the prescriptive fire safety solution, C/AS1 (DBH 2010), includes *accessible*, *accessible route* and *accessible stairway*. Definitions for these are as follows:

- *Accessible* "*Having features to permit use by a person with a disability*." (Definitions, C/AS1 (DBH 2010) and D/AS1 (DBH 2001)
- *Accessible route* "*An access route usable by a person with a disability. It shall be a continuous route that can be negotiated unaided by a wheelchair user. The*

route shall extend from street boundary or car parking area to those spaces within the building required to be accessible to enable a person with a disability to carry out normal activities and processes within the building." (Definitions, C/AS1 (DBH 2010) and D/AS1 (DBH 2001))

- *Accessible stairway* "*A stairway having features for use by a person with a disability. Buildings required to be accessible shall have at least one accessible stairway leading off an accessible route whether or not a lift is provided*." (Definitions, C/AS1 (DBH 2010) and D/AS1 (DBH 2001))

4.2 Single Escape Routes

Single escape routes are allowed for residential purpose groups (SA and SR) where there are no greater than 10 people with disabilities (including children receiving care) on any floor, in addition to other prescriptive requirements. (Paragraph 3.15.1, C/AS1 (DBH 2010))

4.3 Doors into or within Escape Routes

Other than permitted exceptions, doors into and within escape routes are required to (Paragraph 3.17.1, C/AS1 (DBH 2010)):

- be hinged or pivoted on one vertical edge only,
- be self-closing, (There is a comment, in Appendix C, Paragraph 7.1.5, C/AS1 (DBH 2010) stating the "self-closers can be an obstruction to elderly and people with disabilities, who have difficulty in opening the door against the pressure applied by the self-closer". So might people with temporary disabilities, such as crutches, etc. This is congruent with the C/AS1 (DBH 2010) definition of 'person with disability'.)
- be fitted with panic bolts,
- not be fitted with any locking device, with permitted exceptions,
- have door handles which satisfy the requirements for use by people with disabilities,
- have an opening force that does not exceed 67 N to release the latch, 133 N to set the door in motion, and 67 N to open the door to the minimum width required,
- if an electromechanical type door, fail to a safe, readily operable condition.

It is important to establish the relationship between requiring door handles for use by people with disabilities and the stated maximum opening forces allowable.

4.4 Minimum Width of Escape Routes

Minimum escape route widths are prescribed for several purpose groups, including residential purpose groups (i.e. SA and SR), as:

- 850 mm for horizontal travel and 1000 mm for vertical travel, or

- 700 mm for horizontal travel and 850 mm for vertical travel, where there is no requirement to provide for people with disabilities and the occupant load is less than 50 people.

This implies that people with disabilities have been considered in the prescription of minimum escape widths of 850 mm for horizontal travel and 1000 mm for vertical travel. However it is not explicitly stated within the document as to when there is or is not a requirement to provide for people with disabilities.

4.5 Handrails and Stair Widths

The comment of Paragraph 3.3.3 requires accessible stairs to have handrails on both sides and any other stairways to have at least one handrail, according to D1/AS1, Paragraph 6.0.

4.6 Obstructions within Stairways

The minimum width required between faces of the handrails, according to D1/AS1, is 900 mm, however this is not required in vertical safe paths where refuge areas are provided. (Comment of Paragraph 3.3.6, C/AS1 (DBH 2010)) However there is no requirement for refuge areas for SA or SR in the prescriptive code (Paragraph 3.13 and Table 4.1, C/AS1 (DBH 2010). Therefore escaping occupants are assumed to wait in the refuge areas until the escape route is clear enough for them to negotiate the stairway to self-rescue or to wait for assistance to escape.

4.7 Accessible Escape Routes

Only an escape route that coincides with an accessible route must be accessible, with a minimum width of 1200 mm, in accordance with D1/AS1. (Paragraph 3.3.7, C/AS1 (DBH 2010) and Paragraphs 1.5.5, 2.2.1, 3.2, D/AS1 (DBH 2001)) Open paths (i.e. not protected from fire or smoke) within escape routes that are not required to be accessible routes allow reduced minimum widths for escape routes and door widths. (Paragraphs 3.3.7 and 3.17.5, C/AS1 (DBH 2010))

There is no requirement in C/AS1 (DBH 2010) for an accessible escape route to be present.

In addition, considering the stated assumption that "all people will be travelling in the same direction during an evacuation" (Comment in Paragraph 3.3.7, C/AS1 (DBH 2010)), there is no provision for entry of emergency responders to enter via the escape route. This implies that the design is for people in refuge areas, who are waiting for assistance, and must rely on assistance behaviour of fellow able-bodied occupants or wait for emergency responders to be able to make their way into the building and find them. (It has been noted internationally where accessibility requirements during normal do not extend to emergency evacuation requirements, e.g. Ono and Valentin (2009).)

4.7.1 Accessible Routes

Where an accessible route is required in a building, at least one route is required to have features to enable people with disabilities to:

- "approach the building from the street... or building carpark",

- “have access to the internal space served by the principal access” and
- “have access to and within those spaces where they may be expected to work or visit, or which contain facilities for personal hygiene...”.(D.1.3.2, Building Regulations 1992)

In addition to all the usual requirements of access routes (as required by D.1.3.3, Building Regulations 1992), an accessible route must also:

- “be easy to find, as required by Clause F8 ‘Signs’”, (F8/AS1 (DBH 1993))
- “have adequate activity space to enable a person in a wheelchair to negotiate the route while permitting an ambulant person to pass”,
- “include a lift complying with Clause D2 ‘Mechanical Installations for Access’ to upper floors where” any of the follow apply:
    - “buildings are four or more storeys high”,
    - “buildings are three storeys high and have a total design occupancy of 50 or more persons on the two upper floors”,
    - “buildings are two storeys high and have a total design occupancy of 40 or more persons on the upper floor”, or
    - “an upper floor, irrespective of design occupancy, is to be used for the purposes of public reception areas of banks, central, regional and local government offices and facilities, hospitals, medical and dental surgeries, and medical pharamedical and other primary health care centres”.
- “contain no thresholds or upstands forming a barrier to an unaided wheelchair user”,
- “have means to prevent the wheel or a wheelchair dropping over the side of the accessible route”,
- “have doors and related hardware which are easily used”,
- “not include spiral stairs, or stairs having open risers”,
- “”have stair treads with leading edge which is rounded”, and
- “have handrails on both sides of the accessible route when the slope of the route exceeds 1 in 20...”. (D.1.3.4, Building Regulations 1992)

There is no requirement for an accessible escape route for people with disabilities to safely escape from a building in the event of an emergency, such as a fire. The only accessibility in escape routes required is when the protected path of an escape route happens to coincide with an accessible route.

4.8 Alarm Systems

All local fire alarms using smoke detection are required to have a silencing (or ‘hush’) switch located at an accessible level, in accordance with D1/AS1. (Appendix A, Type 5.a, C/AS1 (DBH 2010))

For fire safety precautions numbered 2 to 7, where a system serves the SA purpose group, alerting devices are required to be installed in every accommodation unit provided for the use of persons with a disability. (Paragraph 2.1.2.d, F7/AS1 (DBH 2008)) In addition, where persons with a disability are employed, alerting devices are required to have both audible and visual warning signals. (Paragraph 2.1.2.f, F7/AS1 (DBH 2008))

5. GENERAL GUIDANCE FOR IDENTIFYING A SET OF DESIGN FIRE-SAFETY SCENARIOS

To assess the appropriateness of a performance-based building design, the building design must be challenged with a selection of fire-safety scenarios that are related to the intended building occupancy, functionality and usage for specific fire-safety objectives. A proposed general approach for identifying a set of design fire-safety scenarios for any specified fire-safety objective has been developed by Robbins Gwynne and Kuligowsik (2011) in response to discussions at the meeting of ISO/TC92/SC4/WG11 of the scope and intention of the proposed draft of ISO/WD 29761 Fire safety engineering – Selection of design occupant behavioural scenarios and design behaviours. This proposed general approach for fire-safety scenario selection is designed for application to fire, egress and/or structural analyses. A draft of the proposed approach can be found in Robbins, Gwynne and Kuligowski (2011).

A draft of a worked example (produced by A.P. Robbins to ISO/TC92/SC4/WG11 in consideration of the scope and intention of ISO/WD 29761) applying this framework for fire-safety objectives of life-safety of intended occupants and life-safety of fire-fighters for a residential building design intended for an occupancy of older adults is included in Appendix A.

5.1 Seven Step Framework

The key aspects of the proposed scenario selection process are:

- Preparation of the fire-safety analysis:
    - defining the design to be analysed, and
    - identifying the intention of the analysis in terms of objectives and acceptance criteria.
- Identification of a comprehensive set of possible fire-safety scenarios based on key model factors:
    - considerations include the assumptions and limitations for the translation of real world scenarios and factors into model scenarios and factors.
- Managing the set of scenarios:
    - clustering similar possible fire-safety scenarios,
    - prioritising the sets of clustered of fire-safety scenarios, and
    - documenting the final set of fire-safety scenarios to be used as design fire-safety scenarios, including assumptions and limitations.

These key aspects provide the framework for the seven steps of a systematic approach to identify a suite of design fire-safety scenarios appropriate to challenge a building design, with the intended functionality and usage, for stated fire-safety objectives.

The proposed general approach to identifying fire-safety scenarios is outlined in the schematic of Figure 27.

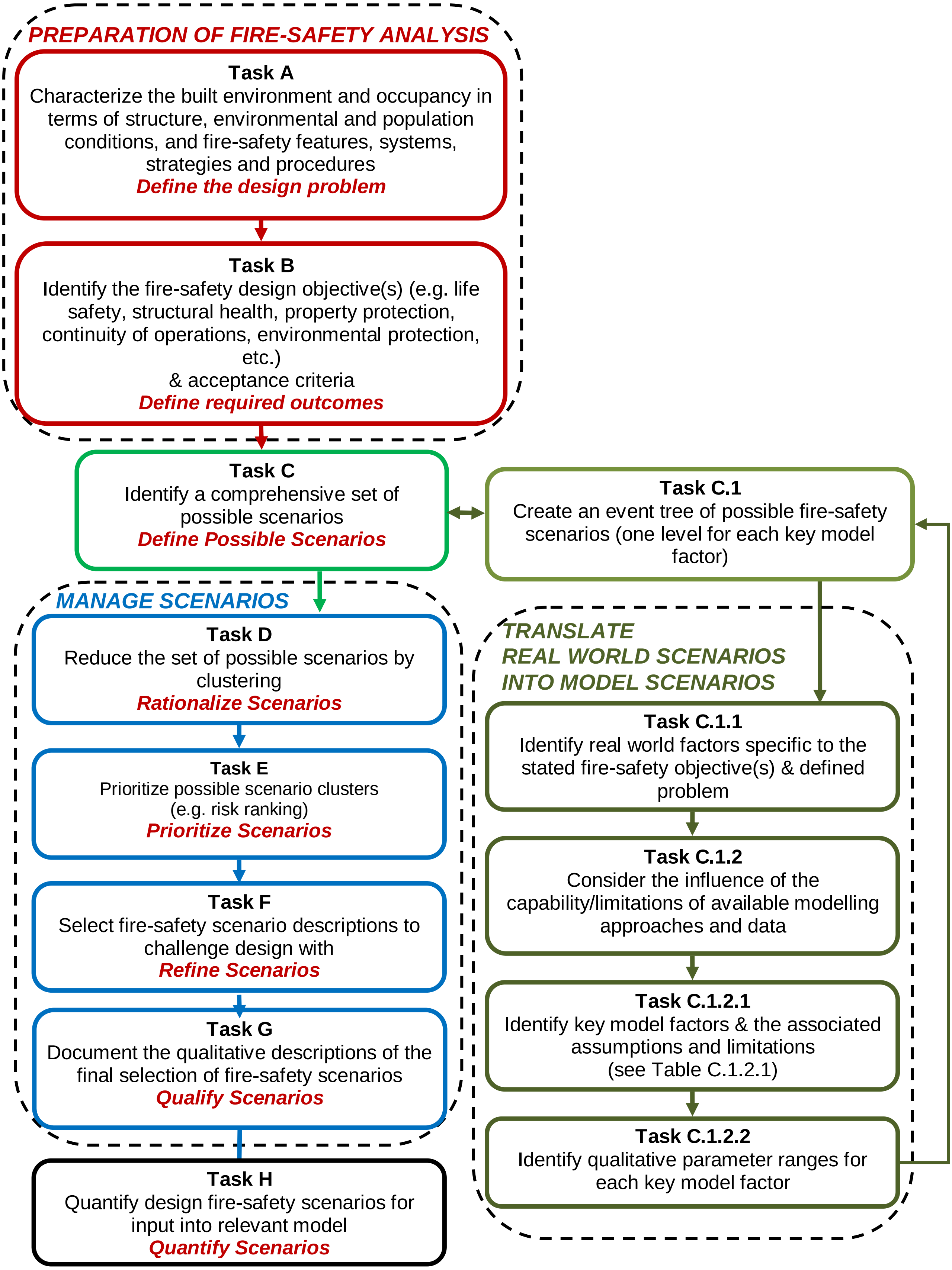

Figure 27: General approach to identify fire-safety scenarios. Extracted from the draft proposal to ISO/TC92/SC4/WG11 (Robbins, Gwynne and Kuligowski (2011) and Error! Reference source not found.**).**

5.2 Considering Older Adult Residential Occupancies

In the proposed general framework for selection of fire-safety design scenarios, there are two specific Tasks (Task A and parts 1.2.1 and 1.2.2 of Task C) where there will be differences between the approaches required for assessing an general residential occupancy and an older adult residential occupancy.

Specifically, an intended building may have one occupancy or a number of types of occupancies, since a building may be expected to have different occupancies related to each type of usage of the building spaces that also might vary at different times of the day or over seasons, etc. Each type of usage of the building and the associated occupancy needs to be described as part of the initial preparation and definition of the entire design problem being considered, at Task A. This is where an intended occupancy of older adults would be initially described using this framework.

Furthermore, when considering the key model factors (Task C.1.2.1) and the associated qualitative parameter ranges (Task C.1.2.2), these will be different when considering a residential occupancy representing all aspects of the general population proportionally compared to an older adult residential occupancy.

Application of the proposed framework for selecting fire-safety scenarios to use to assess a proposed building design must be specific to the building design, the intended usage of the building space, the intended occupancy and the stated fire-safety design objectives.

For an example of applying this framework for fire-safety objectives of life-safety of intended occupants and life-safety of fire-fighters for a residential building design intended for an occupancy of older adults, see Appendix A

6. SUMMARY AND CONCLUSIONS

Age alone does not provide a direct measure of capability in terms of successful self-evacuation of a building. There are many aspects of an individual's ability to identify an incident, respond with a self-evacuation plan and execute a plan or gain assistance to escape.

The older adult residential population may also be classified as disabled or impaired, other than just age-related changes in capabilities and limitations. In addition, some disability-related information may also be useful to provide comparison for areas where older adult related information is limited or lacking. Therefore disabled and impaired population information was included in this study.

When considering the range of capabilities of a building occupancy to successfully escape, one consideration is that the capabilities of 'persons with disabilities' cover a broad spectrum of attributes and levels of ability regarding self-rescue and typically does not include persons with temporary disabilities, who would usually be considered able-bodied but would have a range of capabilities and limitations that would complicate their escape.

Metrics that would be of use when characterising an intended building occupancy for emergency evacuation during a fire may include:

- Physical functionality:
    - Mobility, e.g. movement on horizontal or inclined planes or stairs
    - Agility, e.g. getting in and out of bed or a chair
    - Dexterity, e.g. using door knobs, etc.
- Sensory functionality:
    - Sight
    - Hearing
    - Touch
    - Smell
- Cognitive functionality:
    - Concentration
    - Comprehension
    - Memory
    - Ability to learn

Data sets collected from various surveys (e.g. for healthcare, disability access, assisted care programs, etc.) must be considered in context of the initial collection intent and how that influences the range of results in terms of the applicability of use characterising intended building occupants during an emergency event.

Design of buildings to facilitate access for people with disabilities during normal activities is fundamentally different to design of accessible emergency escape.

Currently, in New Zealand, the inclusion of accessibility for normal activities is common design practice (e.g. it is included in prescriptive solutions such as D1/AS1 (DBH

2001)), whereby ensuring people with disabilities have safe access into and out of a building during non-emergency situations, where required. Whereas the accessible emergency escape routes are not typically included in prescriptive solutions (e.g. an escape route is only required to be accessible if it happens to coincide with an accessible route according to C/AS1 (DBH 2010)). Therefore people with disabilities may gain access to a building via an accessible route but may have to use a non-accessible escape route during an emergency evacuation.

Another consideration is the ease of use or ergonomics of aspects of building designs intended for 'person with disabilities' for persons without disabilities. In addition, potential conflicts in aspects of building designs might occur between different types of disabilities.

Design solutions for accessible routes may not directly translate for accessible escape routes. Considering the differences between normal building access, or even non-emergency pre-advertised evacuation drills, and emergency evacuation, accessibility must be considered as part of the building design in the context in which it is intended for use. That is, an accessible route is not an accessible escape route. Similarly, an escape route is not an accessible escape route.

For performance-based design, a draft for a common framework, and a worked example using this draft framework, to be used in selection of fire-safety scenarios for the assessment of performance-based building designs that has been submitted for consideration to ISO/TC92/SC4/WG11 for potential inclusion in the proposed draft of ISO/WD 29761 Fire safety engineering – Selection of design occupant behavioural scenarios and design behaviours were included and discussed in terms of potential application to residential buildings with intended older adult occupancies.

6.1 Recommendations

Recommendations for future research include:

- Collection and collation of age-related functionality related to self-rescue and emergency egress from buildings.
    - Collate data and fill voids to create usable distributions of metrics that can be used in design analysis for:
        - General population occupancy (with full age and disability contributions), and
        - Older adult occupancy (65+ years).
    - Include a sensitivity analysis related to changes in distribution of age.
    - Integrate an age-related component to existing quantitative surveys in complementary fields, such as healthcare and disability.
- Development of guidance for best practice for ‘accessible escape route’ design.
    - For buildings that currently require accessible routes, include requirements for accessible escape routes.
- Investigation of the possible approaches to fire safety design to identify the best ways to analyse designs with:
    - intended occupancies are that are well described and characterised to ensure that the range of capabilities and limitations are included
    - identify potential conflicts between building feature requirements for different types of disability
    - assist finding design solutions that accommodate a range of capabilities and limitations including people with and without disabilities.

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APPENDIX A DRAFT OF A WORKED EXAMPLE FOR IDENTIFYING A SET OF DESIGN FIRE-SAFETY SCENARIOS: RESIDENTIAL BUILDING TARGETED AT RETIREES

(As submitted to ISO/TC92/SC4/WG11 by A. P. Robbins, January 2011, for consideration by the members of the working group for inclusion in the proposed draft of ISO/WD 29761 Fire safety engineering – Selection of design occupant behavioural scenarios and design behaviours.)

All data, values and distributions (both qualitative and quantitative) used in this worked example are for demonstration purposes only. The design presented here was developed for demonstrate purposes only.

A.1 Task A: Define the design problem

Scope of the intention of the design:
The building is an apartment building consisting of serviced apartments, available for purchase by the general population but targeted to the lifestyle of the independent retiree in a community setting. Additionally, there are communal dining, living areas, fitness facilities, sanitary facilities, a kitchen with a communal eating area, an events area, sunrooms with kitchenettes (offering coffee, tea and microwave facilities), a central atrium and staff office areas.
The building consists of three levels interconnected with ramps, stairs and elevators with a central atrium.
The occupant numbers and general description, and built environment description are described below.

A.2 Intended building usage

The intended usage of the building is:

- Usage 1: For the majority of the time,
    - residential, where the occupants are long-term and either own or rent their apartment or suite;
    - staff services are management and kitchen, no on-site care is included;
    - visitors of the residential occupants may be day-time only or overnight;
    - visitors for maintenance services are overseen by building management.
- Usage 2: Regular events or meetings:
    - such as fitness classes, community meetings, etc. may be associated with assemblies of the majority of the residential occupants or a sub-set of these. These events may include visitors, either conducting the event or as participants.
- Usage 3: Special events:
    - such as holiday or birthday parties, etc. may be associated with assemblies of the residential occupants and their visitors in the eating or other areas. It would be likely that such events and seasons of the year will be associated with decorations of the inside and outside of the building.

A.2.1 Building occupant number and general characteristics

There are three main types of intended occupants: residential, staff and visitors. The occupant characteristics and numbers are described in the following table.

Table 30: General characteristics of occupant types

Occupant Characteristics	**Building Occupancy Descriptions**		
	Residential occupancy	**Staff**	**Visitors (friends, family, contractors (e.g. maintenance, etc.))**
Number of persons	50 to 86 persons	6 persons	Up to 190 persons
Age Range	40+ years	18 – 65 years	0+ years
Relation to overall population	working/semi-working/retired population	working population	overall population
Awake/Asleep	fully awake to fully asleep	fully awake	fully awake to fully asleep
Incapacitation	intoxication to incapacitation due to alcohol or medications	no intoxication	no intoxication to incapacitation due to alcohol or medications
Familiarity with the building layout and evacuation strategies	moderate to high	high	low to moderate

An estimate of the building residential occupancy age distribution is shown in the following figure.

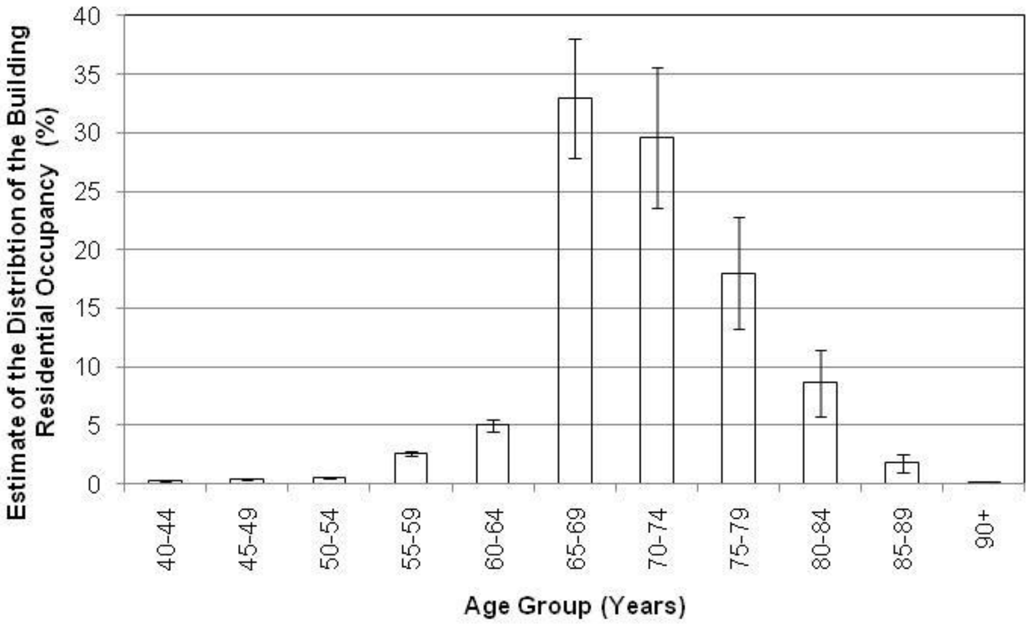


Figure 28: An estimate of the distribution of the age groups of the intended building residents as a percentage.

An estimate of the building staff age distribution is shown in the following figure.

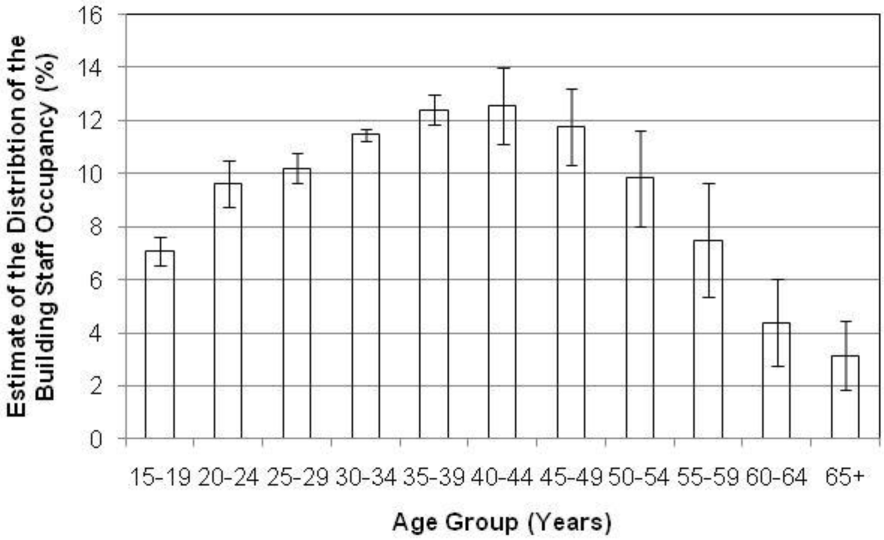


Figure 29: An estimate of the age group distribution of the intended building staff based on the age distribution of the working New Zealand population 1996, 2001 and 2006 census data (SNZ 2007).

An estimate of the building visitor age distribution is shown in the following figure.

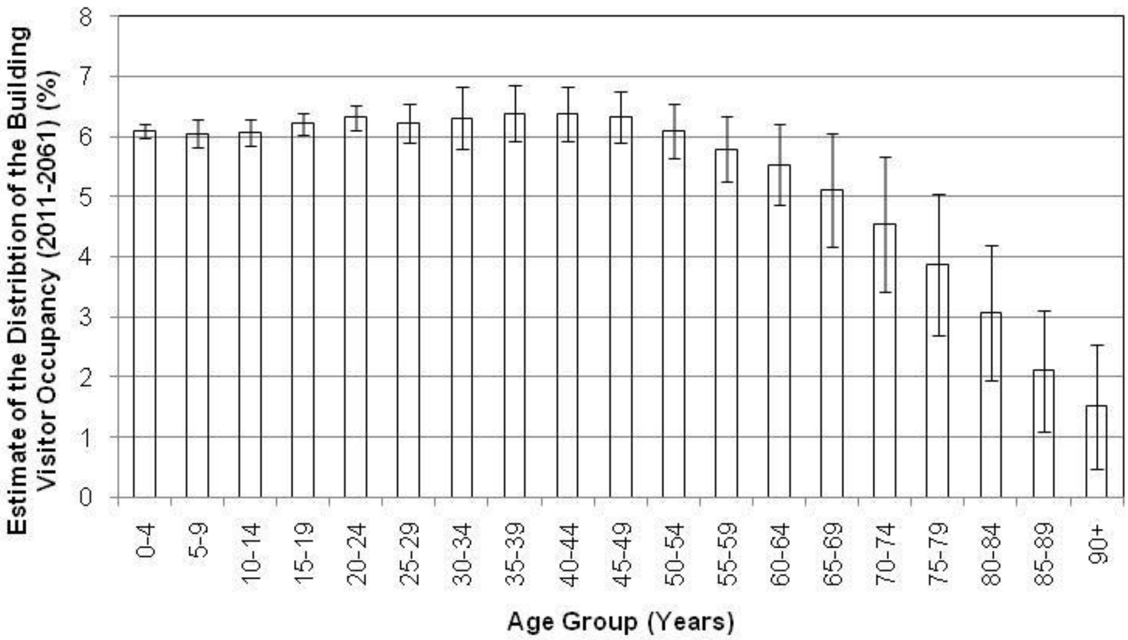


Figure 30: An estimate of the age distribution of the intended building visitors based on averages of the predictions of the New Zealand population (2011 to 2061) estimated from 2006 census data (SNZ 2008).

A.2.2 Built environment description

Built environment:

- internal and external geometry of the structure:
  - the building site is a flat section
  - the internal and external geometry of the building is as shown in the example building Drawing No. 1 to 5.
- structural loadings are not included in this example at this time
- building materials and construction:
  - floor and main walls: concrete slab construction
  - internal walls: wood framed, plasterboard construction
  - external doors and internal walkway doors: glass panel with aluminium frame construction
  - windows: glass panel with aluminium frame construction

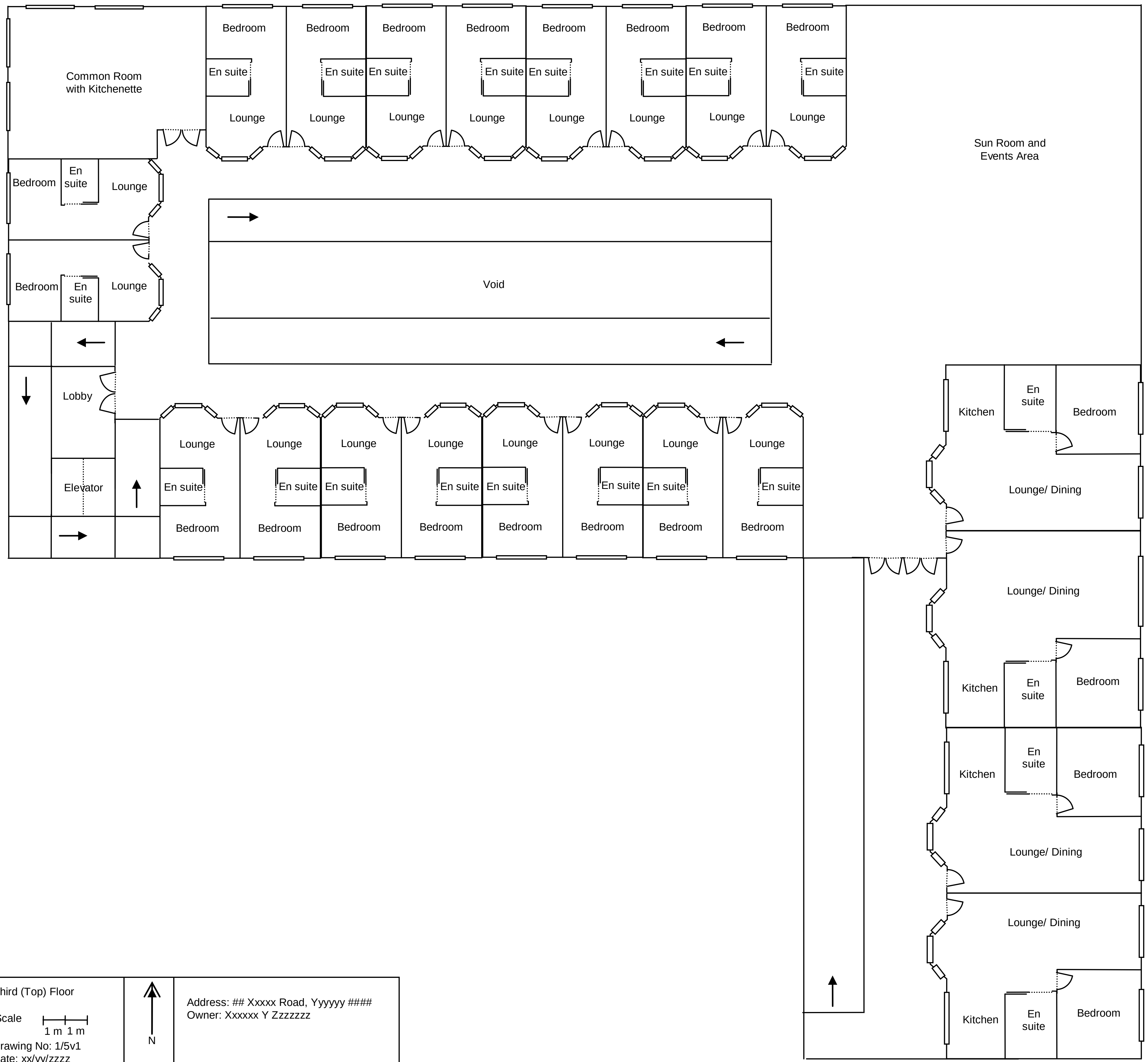
- apartment front doors: solid wood with smoke seals at head and jamb and open-assisted closers

- environmental conditions:
  - this example location is Wellington, New Zealand
  - expected minimum and maximum temperatures are of the range -2 to 32°C (NIWA 2001)
  - wind speeds, with wind gusting to 100 km/h (VU 2010; Ciflo 2010)
  - earthquake prone region (GeoNet 2010)
  - extreme weather/environmental conditions to be expected:
    - high wind gusts
    - earthquakes

- active and passive fire-safety features, systems, strategies and procedures:
  - Descriptions of final exits (as indicated on Drawing No. 3/5v1):
    - FE1: through foyer doors and into the open carparking area
    - FE2: through atrium doors, clearing the building line and into the open carparking area
    - FE3: through west building doors, either from atrium, elevator lobby or common room, along the west side of the building until clearing the building and entering the open carparking area
    - FE4: the end of the ramp down from the second level of the south-east wing, clearing the building and entering the open carparking area.
  - Descriptions of fire compartments:
    - each apartment is a fire compartment
    - the elevator shaft, including the machine room is a protected shaft
    - each common room and room designated for building facilities (i.e. laundry room, fitness centre, management office, and kitchen) are individual firecells
  - Summary of active fire safety systems
    - an automatic sprinkler system installed throughout building, including external walkways, to NZS 4541 (2007)
    - automatic smoke detection installed throughout residential, communal areas and management areas to NZS 4512 (2010)
    - manual alarms installed throughout building to NZS 4512 (2010)
    - automatic heat detection installed throughout kitchen and laundry areas to NZS (2010)
    - smoke venting in atrium roof designed and installed to AS 2665 (2001) (System has manual override. Make up air is provided at ground level by opening of final exit doors, FE1 and FE2. The doors at these make up air locations have smoke detector override to close if smoke is drawn in through the doorways.)
    - emergency lighting installed throughout the building to AS/NZS 2293.1 (1998)
    - electro-magnetic hold-open devices interconnected with the alarm system and self-closing devices, with a fail-safe to ensure closing in the case of power loss,

are installed for all doors throughout the building as described in NZS 4520 (2010)
- door opening assistance devices, with a fail-safe to ensure ease of opening in the case of power loss, are installed for all doors throughout the building to NZS 4121 (2001)
- the alarm system is an automated voice command alarm designed and installed to NZS 4521 (2010)
- an emergency electrical power supply is designed and installed to ensure the continued operation during evacuation of essential fire safety and evacuation features
- an evacuation management plan and training is implemented by the building staff to confirm the presence of fire, close the openings of the compartment involved in fire, systematically check each apartment is clear, assist other occupants to escape, relate building and fire event information to the emergency dispatcher and responders, based on the New Zealand Fire Service Guide to Evacuation Schemes (NZFS 2010)
- a fire systems centre for use by emergency responders is located on the outside of the south wall of the south-east wing of the building based on guidance provided for New Zealand Fire Service operations in buildings (NZFS 2007)

— Summary of passive fire safety systems
- firecells are separated vertically by bounding construction achieving fire resistance rating of no less than 180/180/180, from underneath the construction
- residential firecells are separated horizontally by bounding construction achieving fire resistance rating of no less than 30/30/30
- building services firecells are separated horizontally by bounding construction achieving fire resistance rating of no less than 90/90/90
- escaping occupants are protected from thermal exposure through glass in exitways by both distance available to pass in front of the glass and an option to escape in another direction.



Third (Top) Floor

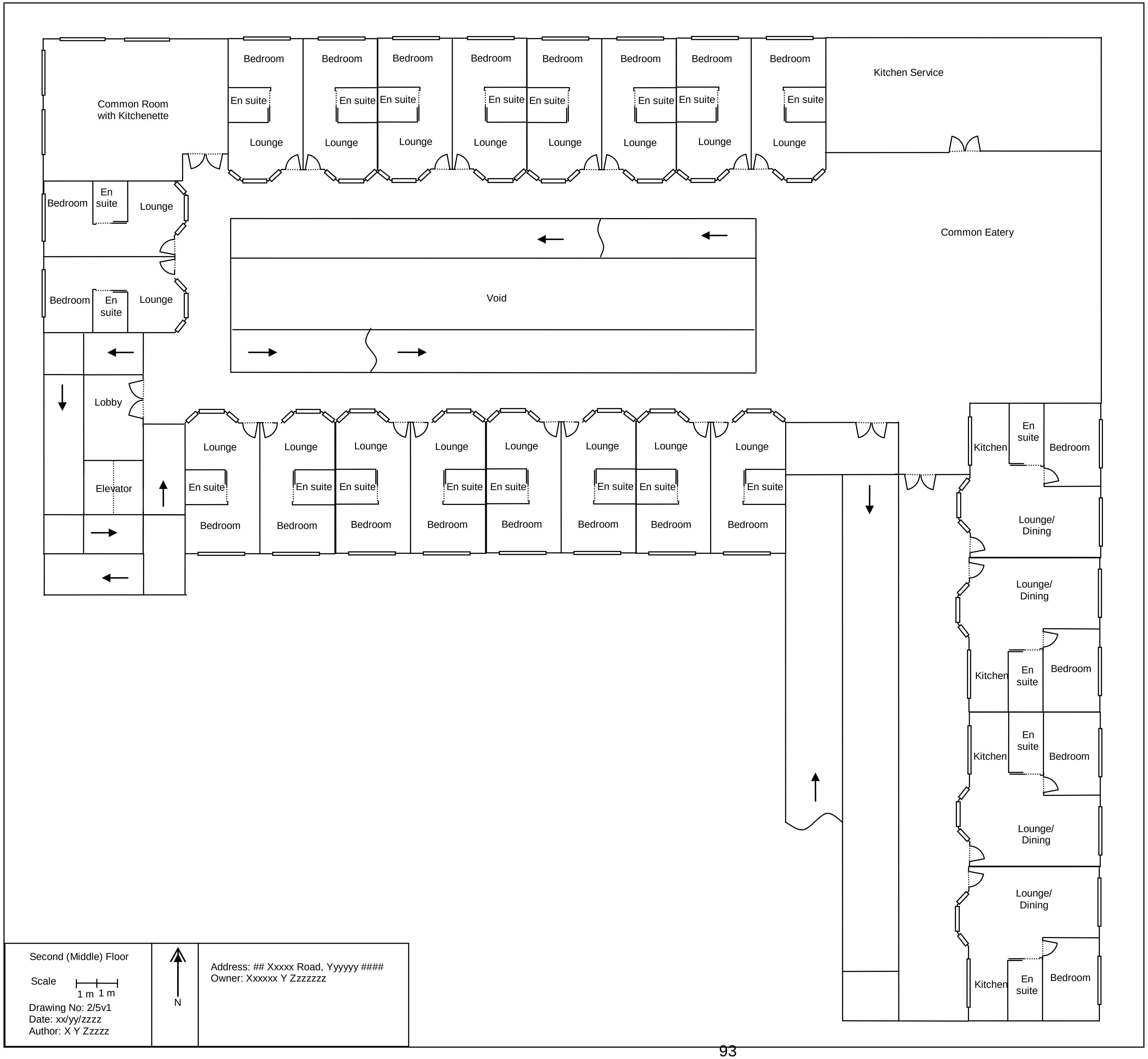
Scale 1 m 1 m

Drawing No: 1/5v1
Date: xx/yy/zzzz
Author: X Y Zzzzz

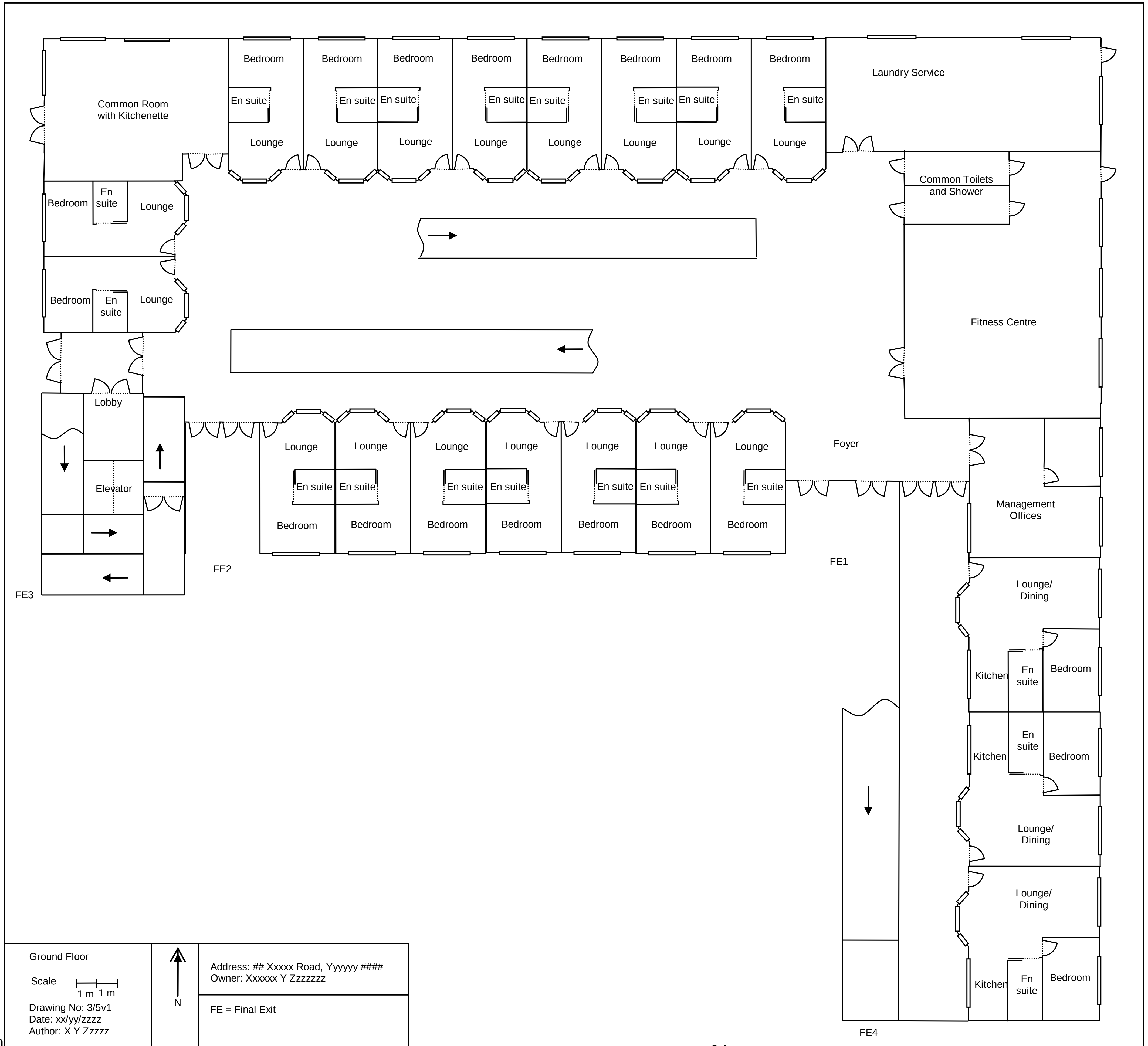
N

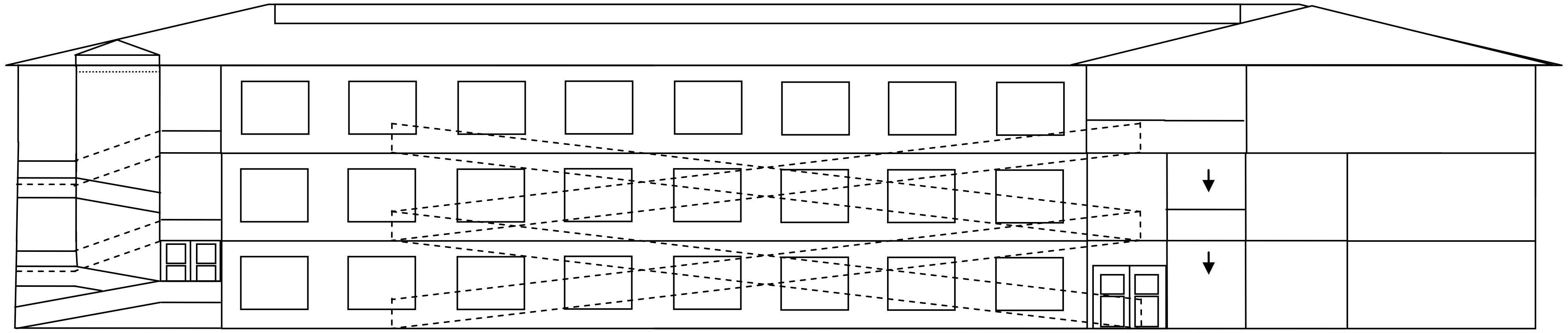
Address: ## Xxxxx Road, Yyyyyy ####
Owner: Xxxxxx Y Zzzzzzz

h



Common Room
with Kitchenette
Bedroom
En suite
Lounge
Kitchen Service
Common Eatery
En
suite
Void
Lobby
Elevator
Kitchen
Lounge/
Dining
Second (Middle) Floor
Scale
1 m 1 m
Drawing No: 2/5v1
Date: xx/yy/zzzz
Author: X Y Zzzzz
N
Address: ## Xxxxx Road, Yyyyyy ####
Owner: Xxxxxx Y Zzzzzzz


Common Room
with Kitchenette
Bedroom
En suite
Lounge
Laundry Service
Common Toilets
and Shower
Fitness Centre
Bedroom
En
suite
Lounge
Lobby
Elevator
Foyer
Management
Offices
Lounge/
Dining
Kitchen
Bedroom
FE1
FE2
FE3
FE4
Ground Floor
Scale
1 m 1 m
Drawing No: 3/5v1
Date: xx/yy/zzzz
Author: X Y Zzzzz
N
Address: ## Xxxxx Road, Yyyyyy ####
Owner: Xxxxxx Y Zzzzzzz
FE = Final Exit
n



South Elevation

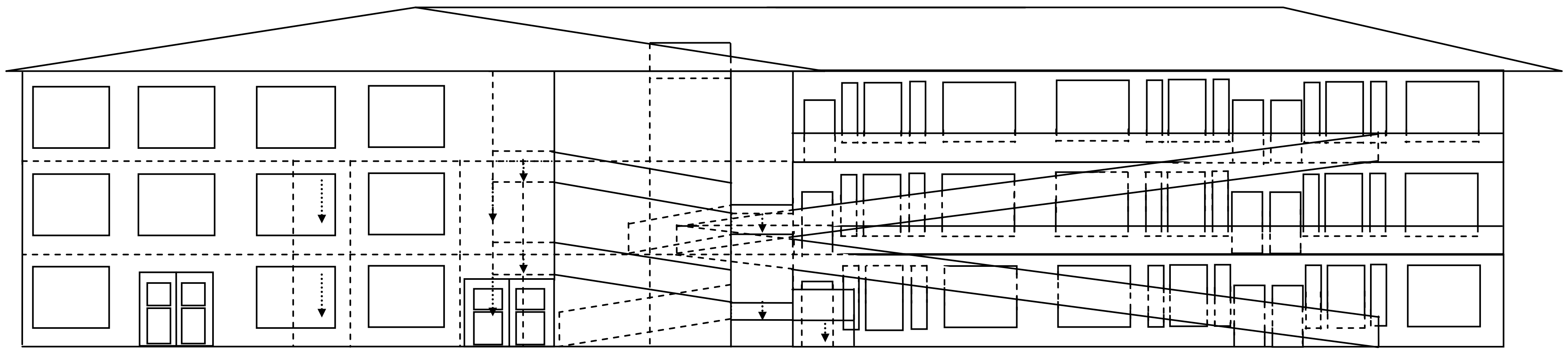
Scale

1 m 1 m

Drawing No: 4/5v1
Date: xx/yy/zzzz
Author: X Y Zzzzz

Address: ## Xxxxx Road, Yyyyyy ####
Owner: Xxxxxx Y Zzzzzzz

Note: only hidden detail pertaining to stairways and ramps in included on this drawing



West Elevation

Scale

1 m 1 m

Drawing No: 5/5v1
Date: xx/yy/zzzz
Author: X Y Zzzzz

Address: ## Xxxxx Road, Yyyyyy ####
Owner: Xxxxxx Y Zzzzzzz

Note: only hidden detail pertaining to stairways and ramps in included on this drawing

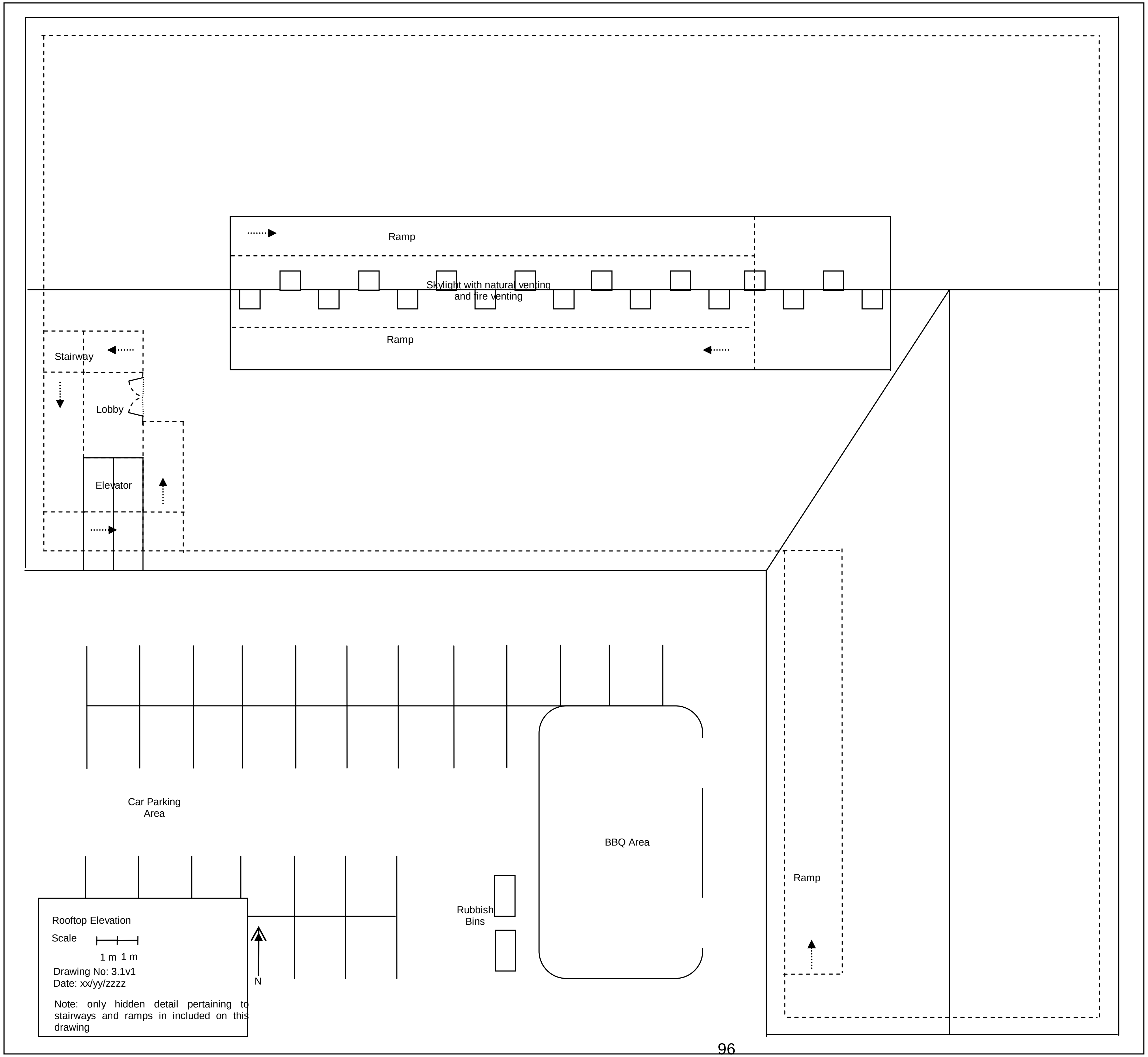

Ramp
Skylight with natural venting and fire venting
Ramp
Stairway
Lobby
Elevator
Car Parking Area
BBQ Area
Ramp
Rubbish Bins
N
Rooftop Elevation
Scale
1 m 1 m
Drawing No: 3.1v1
Date: xx/yy/zzzz
Note: only hidden detail pertaining to stairways and ramps in included on this drawing

Table 31: Summary of building firecells

Level	Firecell Description	Expected Occupant Types	Approx. Occupant Density when in Use (ppl/m^2)	Max. Occupant Load (staff/residents/visitors)			
				Usage 1, day	Usage 1, night	Usage 2	Usage 3
G	Atrium (ground level)	residents, visitors	0.1	-/4/2	-/-/-	-/61/20	-/-/-
G	Management office	staff, residents, visitors	0.1	2/-/1	1/-/-	2/-/-	1/-/-
G	Laundry	staff, residents	0.1	2/1/-	-/-/-	2/-/-	1/-/-
G	Fitness centre	residents, visitors	0.2	-/2/-	-/-/-	-/-/-	-/-/-
G	Common room with kitchenette	residents, visitors	0.3	-/7/3	-/-/-	-/-/-	-/-/-
G	Apartments	residents, visitors	Based on no. bedrooms	-/7/1	-/21/4	-/2/-	-/2/-
2	Kitchen	staff	0.1	2/-/-	-/-/-	2/-/-	2/-/-
2	Communal eatery	residents, visitors	0.1	-/11/-	-/-/-	-/-/-	-/-/-
2	Common room with kitchenette	residents, visitors	0.3	-/7/-	-/-/-	-/-/-	-/61/60
2	Apartments	residents, visitors	Based on no. bedrooms	-/7/1	-/23/5	-/2/-	-/2/-
3	Sun room and events area	residents, visitors	0.1	-/7/3	-/-/-	-/-/-	2/-/-
3	Common room with kitchenette	residents, visitors	0.3	-/7/3	-/-/-	-/-/-	-/-/-
3	Apartments	residents, visitors	Based on no. bedrooms	-/7/1	-/23/5	-/2/-	-/2/-
	Totals			6/67/15	1/67/14	6/67/20	6/67/60

A.3 Task B: Define required outcomes

The fire-safety design objective:

- life safety of occupants
- life safety of fire fighters

The acceptance criteria that are required to judge the appropriateness of the design for each of the stated objectives are:

- For life safety of occupants:
  - Tenability:
    - Visibility at 2 m above floor height of 15 m
    - Instantaneous carbon monoxide concentration does not exceed 10,000 ppm at 2 m above floor height
    - Fractional effective dose of carbon monoxide does not exceed 0.3
    - Maximum radiant flux at 2 m above floor height of 1.8 kW/m²
    - Maximum gas temperature at 2 m above floor height 60°C
    - Thermal fractional effective dose does not exceed 0.3
    - Structural integrity maintained while occupants are inside
- For life safety of the fire fighters:
  - Tenability:
    - Visibility at 2 m above floor height of 5 m
    - Maximum radiant flux at 2 m above floor height of 2.5 kW/m²
    - Maximum gas temperature at 2 m above floor height 65°C
    - Maximum upper layer gas temperature at ceiling not to exceed 200°C
    - Structural integrity maintained while fire fighters carry out potential rescue and suppression operations

Note: The values for each of these performance criteria, in practice, will be established by agreement between the appropriate regulatory authority or authorities, the building owner and the designer during the QDR phase in order to ensure that the minimum safety level (as required by the regulatory authority) and any intended functionality of the building (as desired by the building owner) above this minimum level are tested during the design analysis and achieved in the final design.

A.4 Task C: Define possible fire-safety scenarios

An event-tree approach is used for this example. A separate event tree is developed for each of the two fire-safety design objectives defined for this example.

A.4.1 Task C.1: Create an event tree

The approach for creating the event tree for this example is to start with an initial event involving an ignition in combination with initial states for all fire safety systems and features and all occupants. In this case a table format is used, where each column represents a level of the tree. The levels of the tree flow from left to right.

Task C.1.1: Identify real world factors

The real world scenarios and key factors specific to the defined design problem and stated fire-safety objective of life safety of occupants.

The approach used in this example to assist in identifying real world factors is systematically moving through the design to consider each of the physical spaces in turn and consider what real world scenarios are possible and identify the key factors involved. This is then supplemented with additional information based on fire-incident statistics, evacuation drills, and test data, where available and relevant to the design problem, as described in Task A, and fire-safety objectives, as defined in Task B.

In addition, the fire-safety scenarios that could arise from the potential fire hazards identified during the QDR phase as associated with the intended use of the property or the design are considered. Other critical high consequence scenarios are also identified for consideration.
Possible scenarios that include failure or partial failure of fire safety features, systems, strategies and procedures, and detrimental actions of people, e.g. poorly trained staff or casual visitors are also considered. Any of these effects could introduce new potential fire-safety scenarios.
Firstly, each physical space of the design problem is considered. The physical spaces for this design problem are listed in the following table.

Table 32: List of physical spaces for consideration in this design problem

Physical Space	
Level	**Description**
G	Atrium (ground level)
G	Management office
G	Laundry
G	Fitness centre
G, 2, 3	Common room with kitchenette
G, 2, 3	Apartments
G, 2, 3	Walkways
2	Kitchen
2	Communal eatery
3	Sun room and events area
3	Elevator lobby
G-3	Stairway
G-3	Elevator shaft and machine room
G(outside)	Carparking (open to air)
G(outside)	BBQ area
G(outside)	Rubbish area
G-3	Outer wall/cladding of building

Fire-safety design objective of occupant life safety

Addressing the first stated fire-safety design objective of life safety of the occupants (in Task B), real world fire scenarios are considered in relation to this design objective.
Considering residential fire statistics for New Zealand, there has been a recent study of the fire scenarios to note for both New Zealand apartments and all residential buildings. The details of this study are not repeated here, but are published in their entirety elsewhere (Robbins and Wade 2010). A summary of the top fire scenarios from the previous study and the relation of each to this design problem are presented in the following table.

Table 33: A summary of the top fire scenarios from an analysis of residential New Zealand fire statistics for reported incidents and building occupant casualties

Physical Space Description	Fire Scenario Description	Relation to Current Design Problem
Kitchen	unattended or careless cooking fire	Relates to the kitchenette, kitchen and within each apartment
Bedroom	deliberate or suspicious ignition	Relates to within each apartment
Bedroom	careless disposal of cigarettes, ashes, etc	Relates to within each apartment
Living or dining room	deliberate or suspicious ignition	Relates to common rooms, events room, eatery and within each apartment
Living or dining room	fire play, recklessness or carelessness	This situation would be more likely to involve a young child, such as might be visiting a resident. Relates to common rooms, events room, eatery and within each apartment
Bedroom	fire play, recklessness or carelessness	This situation would be more likely to involve a young child, such as might be visiting a resident. Relates to within each apartment
Bedroom	an electric blanket or heater fire involving fabrics	Relates to common rooms and within each apartment
Living or dining room	an electrical failure of entertainment equipment or power transfer equipment	Relates to common rooms, event room, eatery and within each apartment
Laundry or bathroom	an electrical failure of clothes washing machine or dryer	Relates to laundry room
Internal pathway	an electrical failure	Relates to walkways

The results from the prior analysis of available New Zealand residential statistics (as summarised in the previous table) are relevant to this design problem, but only as a general overview on the basis of the residential usage of the building.
Analysis results of fire incident statistics available for other countries can also be included to provide a general overview. For example, the leading cause of fire deaths for older adults (aged 50 and older) in the USA is smoking-related fires, followed closely by heating equipment fires. USA statistics also indicate that older adults are more likely than other age groups to be intimately involved with the ignition source (NFPA, 2008).
The real world scenarios are now considered for the specific design problem, as defined in Task A. Each physical space is considered in terms of each of the intended building usages, as described in Task A, as well as the general top fire scenarios indicated by the relevant fire statistics analysis. A summary of the real world scenarios for this design problem is presented in the following table.

Table 34: A summary of real world fire-safety scenarios considered for this design problem for the fire-safety design objective of life-safety of the occupants

Physical Space		Real World Fire-Safety Scenario
Level	**Description**	
G	Atrium (ground level)	electrical fault igniting decorations (e.g. Christmas decorations, etc.) during the night, when most of the occupants are asleep
		electrical fault igniting decorations (e.g. Christmas decorations, etc.) during a one-off event, when there are large number of visitors and most of the occupants are located in the events room on the top floor
		intentional ignition of stacked furniture during the night, when most of the occupants are asleep
G	Management office	electrical fault igniting stored paper during the night, when most of the occupants are asleep
G	Laundry	washer/dryer machine failure igniting contents or nearby materials during the night, when most of the occupants are asleep
G	Fitness centre	electrical failure of a machine or fixture room lining or disused towels during the night, when most of the occupants are asleep
		electrical failure of entertainment equipment or power transfer equipment during the night, when most of the occupants are asleep
G, 2, 3	Common room with kitchenette	microwave failure igniting nearby materials during the night, when most of the occupants are asleep
		unattended or careless cooking fire during the night, when most of the occupants are asleep
		careless disposal of cigarettes, ashes, etc (includes falling asleep) during the night, when most of the occupants are asleep and a few other occupants are also asleep in the common room
		deliberate or suspicious ignition during the night, when most of the occupants are asleep
		fire play, recklessness or carelessness during the night, when most of the occupants are asleep
		electric blanket or heater fire involving fabrics during the night, when most of the occupants are asleep and a few other occupants are also asleep in the common room
		electrical failure of entertainment equipment or power transfer equipment during the night, when most of the occupants are asleep
G, 2, 3	Apartments	unattended or careless cooking fire during the night, when most of the occupants are asleep
		deliberate or suspicious ignition during the night, when most of the occupants are asleep
		careless disposal of cigarettes, ashes, etc (includes falling asleep) during the night, when most of the occupants are asleep
		fire play, recklessness or carelessness during the night, when most of the occupants are asleep
		an electric blanket or heater fire involving fabrics during the night, when most of the occupants are asleep
		electrical failure of entertainment equipment or power transfer equipment during the night, when most of the occupants are asleep
G, 2, 3	Walkways	electrical failure igniting nearby room lining materials during the night, when most of the occupants are asleep
2	Kitchen	unattended or careless cooking fire during the night, when most of the occupants are asleep
		unattended or careless cooking fire during a one-off event, when there are large number of visitors and most of the occupants are located in the events room on the top floor
2	Eatery	electrical failure or knocked over candle(s) igniting nearby tablecloths, upholstered chairs etc. during the night, when most of the occupants are asleep

		electrical failure or knocked over candle(s) igniting nearby tablecloths, upholstered chairs etc. during a one-off event, when there are large number of visitors and most of the occupants are located in the events room on the top floor
		deliberate or suspicious ignition during the night, when most of the occupants are asleep
		deliberate or suspicious ignition during a one-off event, when there are large number of visitors and most of the occupants are located in the events room on the top floor
3	Sun room and events area	electrical failure of entertainment equipment or power transfer equipment igniting nearby stacked upholstered chairs and tables, etc. during the night, when most of the occupants are asleep
		electrical failure igniting nearby stacked upholstered chairs and tables, etc. during a one-off event, when there are large number of visitors and most of the occupants are located in the same room or close by
		deliberate or suspicious ignition during the night, when most of the occupants are asleep
		fire play, recklessness or carelessness during the night, when most of the occupants are asleep
3	Elevator lobby	deliberate or suspicious ignition of room linings or an object brought into the area during the night, when most of the occupants are asleep
G-3	Stairway	deliberate or suspicious ignition of room linings or an object brought into the area during the night, when most of the occupants are asleep
G-3	Elevator shaft and machine room	deliberate or suspicious ignition of an object brought into the area during the night, when most of the occupants are asleep
		electrical failure igniting room linings during the night, when most of the occupants are asleep
G(outside)	Carparking (open to air)	deliberate or suspicious ignition of a vehicle during the night, when most of the occupants are asleep
G(outside)	BBQ area	deliberate or suspicious ignition of outdoor furniture during the night, when most of the occupants are asleep
G(outside)	Rubbish area	careless disposal of hot objects that ignite rubbish during the night, when most of the occupants are asleep
		deliberate or suspicious ignition of rubbish during the night, when most of the occupants are asleep
G-3	Outer wall/cladding of building	exposure fire during the night, when most of the occupants are asleep
		deliberate or suspicious ignition of materials against side of building during the night, when most of the occupants are asleep

A non-exhaustive list of real world factors related to the real world fire-safety scenarios listed above may include, and is not limited to:

— building layout;

— active and passive fire-safety features present and the level of performance, based on degradation, vandalism, housekeeping practices, maintenance and real world scenario versus design scenario used for designing system initially;

— building construction and materials;

— changes of the building materials, components, etc. over time according to operational wear, maintenance, vandalism, etc.;

— changes of the distributions of characteristics of intended population over time;

- distributions of characteristics of intended building occupancies and changes with each variation of building functionality and usage, and time of day, etc.;
- changes to occupant egress due to fire fighter related counter-flow, set up for fire suppression operations, etc.
- intended building functionality and/or usage(s) and changes with different seasons, special one-off events, etc.;
- building contents and changes of materials, distribution throughout building and configuration of contents with each variation of usage and over time;
- potential adverse environmental conditions (e.g. high winds, post-earthquake, etc.)
- potential people interaction with fire start;
- potential ignition sources;
- potential first material ignited;
- potential equipment involved in ignition;
- fire development and spread throughout compartment and building;
- fire effluent spread throughout building; and
- historical fire incident records and testing in terms of:
    - estimated outcomes of casualties, fire losses, average area of structure lost to fire damage, etc.;
    - estimated reliability and effectiveness of active and passive fire-safety features, systems, strategies and procedures, etc.;
    - influence of codes and regulations used for building stock that make up the historic records, compared to the current codes and regulations;
    - influence of differences of actual building functionality and usage on applicability of historic records;
    - influence of changes in population on applicability of historic records; and
    - influence of differences in population, culture and built environment on historic records from other countries.

Fire-safety design objective of fire fighter life safety

Addressing the second stated fire-safety design objective of life safety of the fire fighters (in Task B), real world fire scenarios are considered in relation to this design objective.
Considering residential fire statistics for New Zealand, the available data set on fire fighter casualties is not sufficiently large enough for a useful analysis to be conducted. However since the statistical analysis, discussed above, is based on reported fire incidents, then it can be inferred that fire fighters would be called to the same set of scenarios that the occupants

might experience and larger numbers of occupant casualties may be used to infer that a higher possibility of fire fighter rescue operations might be required.

Using this approach, the real world factors listed above would also apply for the objective of fire fighter life safety, with the addition of:

- changes in fire fighter tactics for suppression operations over time;
- changes in fire fighter tactics for rescue operations over time; and
- changes in fire fighter personal protective gear and equipment over time.

Fire fighter statistics for residential fires from other countries could also be incorporated at this stage. This would introduce additional real-world factors associated with scenarios based on this additional data that would include:

- Differences between the location of the design and the country for which there is statistical information for:
  - building designs;
  - environmental conditions;
  - fire fighting tactics for both suppression and rescue operations; and
  - fire fighters' personal protective gear and equipment.

Therefore the same set of real world fire scenarios are considered, however there are expected to be differences in the prioritizing of the scenarios and later stages of the scenarios may be of more interest regarding the objective of fire fighter life safety compared to occupant life safety.

Task C.1.2: Consider available model capability and limitations

A specific modelling approach or data set is not selected at this point. However the models available at the time of the analysis or to the individual performing the analysis may be limited. Similarly the available relevant data sets may also be limited. The effect these limitations must be taken into account in relation to the influence on the selection of the model scenarios and factors and subsequently on the fire-safety design analysis results.

For this example, the primary considerations in terms of model selection are based on the available model outputs in relation to the acceptance criteria for each fire-safety design objective. That is, for the fire-safety design objective of occupant life safety, the acceptance criteria

Kuligowski, Peacock and Hoskins (2010) present a summary of building evacuation models that may be of use when selecting an appropriate type of approach. The International Survey of computer Models for Fire and Smoke (2008) is one example source of a list summarising a large number of building fire models that may be of use when selecting an appropriate type of approach. In all cases, selecting an appropriate model for the type of situations of interest to the specific problem is the foremost concern.

For this example, for the fire-safety design objective of occupant life safety, the approach selected for the evacuation modelling is a grid approach with the ability to distribute occupants with a range of travel speeds, change pre-movement times and manually block exits to estimate the time to escape in conjunction with hand calculations (with input from the fire analysis for each scenario) to estimate the maximum thermal dose and toxic and irritant gas doses. The approach selected for fire modelling is a combination of zone modelling for the entire building and field modelling for details of the smoke and hot gas movement where scenarios develop spill plumes within the atrium. The approach selected for the structural analysis is field modelling of the thermal loading of selected critical aspects of the building based on a combination of the results from the fire modelling of each scenario and critical structural member of initial design. Hand calculations will then be used to estimate the response of the structural member of interest.

For the fire-safety design objective of fire fighter life safety, the approach selected for fire modelling is a combination of zone modelling for the overall building and field modelling for details of the smoke and hot gas movement where scenarios develop spill plumes within the atrium. The approach selected for the structural analysis is field modelling of the thermal loading of selected critical aspects of the building based on a combination of the results from the fire modelling of each scenario and critical structural member of initial design. Hand calculations will then be used to estimate the response of the structural member of interest.

It is noted that depending on the results of the rationalising of the potential scenarios (Task D), there may be scenarios that are applicable for both the objectives of occupant life safety and fire fighter life safety.

Task C.1.2.1: Identify key model factors

Based on the real world scenarios and related factors, and available modelling approach capabilities and limitations, key model factors and the associated assumptions and limitations are identified. All model factors can be model inputs. Not all modelling approaches make use of or require all the model factors as inputs. Some model inputs may be based on model outputs from another analysis. Some model factors can be combined into a single model input, i.e. a combination of model factors influences a particular model input.

Model factors that cannot be included because of limitations of available modelling approaches or relevant data are recorded along with the reasons why the model factor has not been included in the analysis.

Table 35: Model factors for the worked example fire-safety objective of occupant life-safety

Description of Model Factor for Inclusion in the Worked Example	Egress	Fire	Structure
Building Layout	O	O	O
Non-Emergency Environmental Conditions	O	O	
Fire Start			
Potential Fire Hazards/Ignition Sources		O	O
Location of Ignition	O	O	O
Relative Time of Day for Event Start	O	O	O
Population			
Size	O	X	
Location	O	X	
Characteristics / Distribution	O	X	
Impairments	O		
Activities/Status	O	X	
Commitment/Engagement/Habituation	O		
Language/Cultural	O		
Social Role/Affiliation	O		
Familiarity	O		
Training/Experience	O		
Visual Access	X	O	
Fire & Smoke Development & Spread			
Type of Fire		O	O
Distribution and Types of Fuels/Fire Load Density		O	O
Internal Ventilation Conditions		O	O
External Environmental Conditions		O	O
Fire Size		O	O
Criteria for Fire Spread			O
Status of Exit Routes, incl. opening/closing doors	X	X	
Building Structure			
Structural Members		-	O
Structural Loads			O
Characteristics of Elements and Connections			O
Restraint Conditions			O
Thermal & Mechanical Material Properties			O
Fire-safety systems, features, strategies, and procedures			
Technical – Detection	O	O	
Human – Detection	O	O	
Technical – Notification	O	O	
Human – Notification	O		
Human – Evacuation Procedure/ Strategy	O	O	
Technical – Compartmentation		O	O
Technical – Suppression Systems	O	O	O
Human – Suppression, incl. Fire Fighting	O	O	O
Human Response			
Pre-Evacuation	X		
Assumed Travel Speeds	X		
Attainable Speeds	X		
Route Use	X	X	
Flow Constraints	X		

Table Notes:
O – Factor that is considered for the analysis indicated in the column header.
X – Factor that is considered for the analysis, but the factor is calculated during, or influenced by, another type of analysis or the selection of modelling approach.
- – Factor that could be included in an analysis approach but is not included in the approaches selected for this worked example. Note that this is not an exhaustive list of potential model factors.

Table 36: Model factors for the worked example fire-safety objective of fire fighter life-safety

Description of Model Factor for Inclusion in the Worked Example	Egress	Fire	Structure
Building Layout	-	O	O
Non-Emergency Environmental Conditions	-	O	
Fire Start			
Potential Fire Hazards/Ignition Sources		O	X
Location of Ignition	-	O	X
Relative Time of Day for Event Start	-	O	-
Population			
Size	-	-	
Location	-	-	
Characteristics / Distribution	-	-	
Impairments	-		
Activities/Status	-	-	
Commitment/Engagement/Habituation	-		
Language/Cultural	-		
Social Role/Affiliation	-		
Familiarity	-		
Training/Experience	-		
Visual Access	-	-	
Fire & Smoke Development & Spread			
Type of Fire		O	-
Distribution and Types of Fuels/Fire Load Density		O	-
Internal Ventilation Conditions		O	-
External Environmental Conditions		O	O
Fire Size		O	O
Criteria for Fire Spread			-
Status of Exit Routes, incl. opening/closing doors	-	X	
Building Structure			
Structural Members		-	O
Structural Loads			O
Characteristics of Elements and Connections			O
Restraint Conditions			O
Thermal & Mechanical Material Properties			O
Fire-safety systems, features, strategies, and procedures			
Technical – Detection	-	O	
Human – Detection	-	O	
Technical – Notification	-	O	
Human – Notification	-		
Human – Evacuation Procedure/ Strategy	-	O	
Technical – Compartmentation		O	-
Technical – Suppression Systems	-	O	-
Human – Suppression, incl. Fire Fighting	-	O	-
Human Response			
Pre-Evacuation	-		
Assumed Travel Speeds	-		
Attainable Speeds	-		
Route Use	-	X	
Flow Constraints	-		

Table Notes:
O – Factor that is considered for the analysis indicated in the column header.
X – Factor that is considered for the analysis, but the factor is calculated during, or influenced by, another type of analysis or the selection of modelling approach.
- – Factor that could be included in an analysis approach but is not included in the approaches selected for this worked example. Note that this is not an exhaustive list of potential model factors.

Task C.1.2.2: Identify qualitative ranges

Qualitative parameter ranges or statuses for each key model factor for the analysis for the fire-safety objective of occupant life safety are identified in the following table.

Table 37: Model parameter qualitative ranges, values or statuses related to analyses for occupant life safety and for fire fighter life safety

Description of Model Factor for Consideration	Qualitative Ranges
Building Layout (for both objectives of occupant and fire fighter life safety)	
	• Internal and external spaces – as shown in Drawing No. 1 to 5 • Locations of functionality and usage – as shown on Drawing No. 1 to 3 • Final exits – as shown on Drawing No. 3
Non-Emergency Environmental Conditions (for both objectives of occupant and fire fighter safety)	
	• Expected environmental conditions maximum temperatures, minimum temperatures, wind and earthquake are as described in Task A
Fire Start (for both objectives of occupant and fire fighter life safety)	
Potential Fire Hazards/Ignition Sources	• Descriptive values for intended functionality, contents and usage of the spaces in relation to potential fire starts, as described in Task A and Task C.1.1
Location of Ignition	• Descriptive value of the internal or external space
Relative Time of Day for Event Start	• Usage 1, during day (Usage is as described in Task A) • Usage 1, during night • Usage 2, during day • Usage 3, during day
Population (for only the objective of occupant life safety)	
Size	• Descriptive value: Small, medium, large, crowd, skeleton crew, etc.
Location	• Space in building layout • Assignments to rooms within the building
Characteristics / Distribution	• Occupant Type: Residents, Staff, Visitors (as described in Task A) • Age distributions for each occupant type as described in Task A
Impairments	• Physical: able-bodied to disabled (wheel-chair movement) • Hearing: none, partial, deafness • Visual: none, partial, blindness • Cognitive: None to partial
Activities/Status	• Commitment to activity: none to high • Status: o Awake, drowsy, asleep o Intoxication: None, minor, medium, major
Language/Cultural	• English language, other language
Social Role/Affiliation	• Residents to Residents or Visitors: loose to strong • Staff to residents: medium to strong
Familiarity	• With others, see affiliation • With building: None, low, medium, high (as related to each occupant type as described in Task A)
Training/Experience	• None, low, medium, high (as related to each occupant type as described in Task A)
Visual Access	• None, low, medium, high
Fire & Smoke Development & Spread (for both objectives of occupant and fire fighter safety)	
Type of Fire	• Range: flaming or smouldering
Distribution and Types of Fuels/Fire Load Density	• Contents and furnishings: o Initial status: as new or degraded by age or vandalism, distribution o Initial distribution: uniform, stacked, etc. • Interior and exterior finishing o Initial status: as new or degraded by age or vandalism or

	compromised • Materials control o Status: as new or degraded by age or vandalism
Internal Ventilation Conditions	• Status: o Under-ventilated, fully ventilated
External Environmental Conditions	• Expected environmental conditions maximum temperatures, minimum temperatures, wind and earthquake are as described in Task A
Fire Size	• Growth rate: o Slow, moderate, fast, ultra-fast • Range: o Whether secondary items ignited by fire, etc.
Criteria for Fire Spread	• Spread rate: none, slow, moderate, fast, etc. (depending on location and materials)
Status of Exit Routes, incl. opening/closing doors	• Blocked exit routes: o Block one of each of the main exit routes: stairway, the ramp in the atrium and the ramp on the outside of the building o On a complete electrical failure, opening-assisted closers/doors fail to operate on command
Building Structure (for both objectives of occupant and fire fighter safety)	
Structural Members	• Initial status: as designed or compromised
Structural Loads (e.g. live, dead, wind loads, etc.)	• Range: low, medium, high
Characteristics of Elements and Connections	• Elements: Column, beam, slab, shell, etc. • Connections: Fixed, free, etc.
Restraint Conditions	• Fixed, free, etc.
Thermal & Mechanical Material Properties	• Ranges: low, medium, high thermal and mechanical susceptibility
Fire-safety systems, features, strategies, and procedures (for both objectives of occupant and fire fighter safety)	
Technical – General	• Initial status: present • Performance: performs as designed or with a reduced quality or degree of performance • Reliability: poor, moderate, high
Technical – Detection	• (See examples for 'Technical – General' above)
Human – Detection	• Time to detection: long (it is not desirable for the occupant life safety to rely on human detection)
Technical – Notification	• Information level for occupants: insufficient, or sufficient information • (See examples for 'Technical – General' above)
Human – Notification	• Information level for occupants: insufficient, or sufficient information
Human – Evacuation Procedure/ Strategy	• (See examples for 'Technical – General' above)
Technical – Compartmentation	• (See examples for 'Technical – General' above) • Compartment size range: small to large • Initial status: • Apartment doors and seals: o Initial status: as new or door seal completely missing o Status at start and during fire: open or closed • Walls/ceiling/floor assemblies in Laundry, Kitchen and Common Rooms: o Initial status: as designed or compromised by penetrations • Elevator shaft and machine room: o Initial status: as designed or compromised by penetrations
Technical – Suppression Systems	• (See examples for 'Technical – General' above)
Human – Suppression,	• Occupant efforts:

incl. Fire Fighting	○ Response time: short to long ○ Intervention time: only Staff closing doors ○ Effectiveness of operations: low to high • Fire fighter operations (only considering life safety of occupants and fire fighters and protection of adjacent property, fire fighting operations are not considered in terms of protecting the building or contents of the property of fire origin): ○ Response time: short to long ○ Intervention time: short to long ○ Effectiveness of operations: moderate to high
Human Response (for only the objective of occupant life safety)	
Human Response Factors – in general	• Incorporated in possible modelling approach, only available as a single value model input or incorporated indirectly in a model input
Pre-Evacuation	• Times: range • Behaviours include: information seeking, preparation, helping others (including warning others), and evacuating
Assumed Travel Speeds	• Distributions: unimpaired to impaired
Attainable Speeds	• Range: low to moderate
Route Use	• Descriptive value: one familiar route, nearest
Flow Constraints	• Range: low to high

A.5 Task D: Rationalize scenarios

In a deterministic assessment, a manageable set of design fire-safety scenarios must be selected to represent the range of real world scenarios. Therefore the set of possible scenarios (as summarised in Task C.1.1) was reduced by clustering similar possible scenarios together, as summarised in the following table.

The number of scenarios listed in Task C.1.1 was 164 and 41 for the fire-safety objectives of occupant life safety and fire fighter life safety respectively. This could be a much higher number if these scenario descriptions were expanded at this stage to also include up to 4 major building usages, 2 types of burning (flaming or smouldering), 2 fire ventilation conditions (well- or under-ventilated), whether the fire is shielded or fire protection features (either active or passive) are effective, or are not effective to some extent (e.g. have been removed or disabled, etc.).

The list of rationalized scenarios numbers 38 and 33 for the fire-safety objectives of occupant life safety and fire fighter life safety respectively.

Table 38: A summary of clustered fire-safety scenarios considered for this design problem for the fire-safety design objective of life-safety of the occupants (when 'Building Usage' is included) and of life-safety of fire fighters (when 'Building Usage' is not included)

Physical Space Description	Cause of Ignition	Materials Ignited	Usage	Cluster No.
Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	1 (night)	1a
			3	1b
	deliberate	accelerant on stacked furniture	1 (night)	2
Management office	electrical fault igniting	stored paper during	1 (night)	3
Laundry	washer/dryer machine failure	bundle of fabric	1 (night)	4
Fitness centre	electrical failure	room lining or bundle of fabric	1 (night)	5
Common room with kitchenette	electrical failure	room lining, electronic equipment or bundle of fabric	1 (night)	6
	cigarette	bundle of fabric	1 (night)	7
	deliberate	accelerant on upholstered chairs	1 (night)	8
	fire play	upholstered chair	1 (night)	9
	electric blanket or heater	bundle of fabric	1 (night)	10
Apartments	unattended or careless cooking fire	room lining, or nearby fabric or food/oil	1 (night)	11
	deliberate	accelerant on upholstered furniture	1 (night)	12
	cigarette	bed clothes	1 (night)	13
	fire play	upholstered sofa	1 (night)	14
	electric blanket or heater	bundle of fabrics	1 (night)	15
	electrical failure	room lining, or electronic equipment	1 (night)	16
Walkways	electrical failure	room lining	1 (night)	17
Kitchen	unattended cooking fire	room lining, or nearby fabric or food/oil	1 (night)	18a
			3	18b
Eatery	electrical failure or knocked over candle(s)	bundle of fabric or furniture	1 (night)	19a
			3	19b
	deliberate	accelerant on furniture	1 (night)	20a
			3	20b
Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a smouldering fire)	1 (night)	21a
			3	21b
	deliberate	stacked upholstered chairs and tables, etc.	1 (night)	22
	fire play	upholstered chairs or curtains, etc.	1 (night)	23
Elevator lobby	deliberate	accelerant on room linings or an object brought into the area	1 (night)	24
Stairway	deliberate	accelerant on room linings or an object brought into the area	1 (night)	25
Elevator shaft and machine room	deliberate	accelerant on room linings or an object brought into the area	1 (night)	26
	electrical failure	room linings	1 (night)	27
Carparking (open to air)	deliberate	accelerant on vehicle	1 (night)	28
BBQ area	deliberate	accelerant on stacked outdoor furniture	1 (night)	29
Rubbish area	cigarette	rubbish	1 (night)	30
	deliberate	rubbish	1 (night)	31
Outer wall/cladding	exposure fire	cladding or window breakage	1 (night)	32
	deliberate	accelerant on rubbish or vehicle against	1 (night)	33

of building		side of building		

A.6 Task E: Prioritize scenarios

The scenario clusters were then prioritized. There was insufficient information for a full risk assessment, as described in ISO 16732, to be applied. Therefore the likelihood and consequence for each cluster of scenarios was estimated using available information in combination with engineering judgement to methodically prioritize the scenario clusters.

Each fire-safety objective was considered in turn, since each objective may be associated with a different priority ranking of the clustered scenarios.

A.6.1 Fire-safety design objective of occupant life safety

A summary of the priority ranking of each of the clustered scenarios regarding occupant life safety is presented in the following table. The cluster scenario numbers allocated during Task D are used.

Table 39: Prioritization of numbered scenario clusters for the fire-safety design objective of occupant life safety

		Estimate of Consequence Regarding Occupant Life Safety			
		Low	**Moderate**	**Severe**	**Catastrophic**
Estimate of Likelihood	**Rare**	Low 28, 29, 30, 31	Low 16, 21b, 23, 27	Moderate 3, 5, 6, 8, 9, 12, 17, 20b, 22, 26	Moderately High 2, 20a, 21a, 24, 25, 32, 33
	Unlikely	Low	Moderate 19b	Moderately High 4, 7, 19a	High 1b
	Possible	Moderate	Moderately High 15	Moderately High 10, 13 18a, 18b	High 1a
	Likely	Moderate	High	High 11	High

A.6.2 Fire-safety design objective of fire fighter life safety

A summary of the priority ranking of each of the clustered scenarios regarding fire fighter life safety is presented in the following table. The cluster scenario numbers allocated during Task D are used.

Table 40: Prioritization of numbered scenario clusters for the fire-safety design objective of fire fighter life safety

		Estimate of Consequence Regarding Fire Fighter Life Safety			
		Low	**Moderate**	**Severe**	**Catastrophic**
Estimate of Likelihood	**Rare**	Low 28, 29, 30, 31	Low 16, 23, 27	Moderate 3, 5, 6, 8, 9, 12, 17, 22, 26	Moderately High 2, 20, 21, 24, 25, 32, 33
	Unlikely	Low	Moderate	Moderately High 4, 7, 19	High
	Possible	Moderate	Moderately High 15	Moderately High 10, 13, 18	High 1
	Likely	Moderate	High	High 11	High

A.7 Task F: Refine scenarios

For each fire safety objective, the highest priority clustered scenarios to be used to challenge the design were selected. It is recommended that input from the stakeholders is incorporated into this selection process.

A.7.1 Fire-safety design objective of occupant life safety

A summary of the highest priority clustered scenarios regarding occupant life safety is presented in the following table. The cluster scenario numbers allocated during Task D are used.

Table 41: Refined scenario clusters based on Task E prioritization for the fire-safety design objective of occupant life safety

General Priority Level	Cluster No.	Physical Space Description	Cause of Ignition	Materials First Ignited	Building Usage
High	1a	Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	1 (night)
	11	Apartments	unattended or careless cooking fire	room lining, or nearby fabric or food/oil	1 (night)
	1b	Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	3
Moderately High	10	Common Room with kitchenette	electric blanket or heater	bundle of fabric	1 (night)
	13	Apartments	cigarette	bed clothes	1 (night)
	18a	Kitchen	unattended cooking fire	room lining, or nearby fabric or food/oil	1 (night)
	18b	Kitchen	unattended cooking fire	room lining, or nearby fabric or food/oil	3
	2	Atrium (ground level)	deliberate	accelerant on stacked furniture	1 (night)
	20a	Eatery	deliberate	accelerant on furniture	1 (night)
	21a	Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a smouldering fire)	1 (night)
	24	Elevator lobby	deliberate	accelerant on room linings or an object brought into the area	1 (night)
	25	Stairway	deliberate	accelerant on room linings or an object brought into the area	1 (night)
	32	Outer wall/ cladding	exposure fire	cladding or window breakage	1 (night)
	33	Outer wall/ cladding	deliberate	accelerant on rubbish or vehicle against side of building	1 (night)
	4	Laundry	washer/dryer machine failure	bundle of fabric	1 (night)
	7	Common room with kitchenette	cigarette	bundle of fabric	1 (night)
	19a	Eatery	electrical failure or knocked over candle(s)	bundle of fabric or furniture	1 (night)
	15	Apartment	electric blanket or heater	bundle of fabrics	1 (night)

The top 10 prioritized scenarios are taken as the initial set of refined scenarios. Then the impact of not including the remaining scenarios is considered and any additional refined clustered scenarios are added to the list. The list of refined scenarios is then compared to stakeholder requirements. Note that the stakeholder requirements will vary between design projects and the people who represent the stakeholders for each project.
For this example the stakeholder requirements are:

- Fire in entryway of a principally occupied room
- Fire in a concealed area
- Fire in a structural area
- Smouldering fire in a principally occupied room
- Exposure fire
- Fire blocking an exitway
- Shielded room corner fire

A summary of the refined scenarios with the reasons for inclusion are presented in the following table.

Table 42: Refined scenarios with reasons for inclusion for the fire-safety design objective of occupant life safety. (Shaded rows have been combined into the scenario directly above the shaded cluster.)

Reasons for Inclusion in Refined Scenarios	Physical Space Description	Cause of Ignition	Materials First Ignited	Building Usage
Combining the next 6 refined scenarios into 1 worst-case scenario	Atrium (ground level, under the walkway area near the stairs)	deliberate	accelerant on stacked furniture	1 (night)
Top 10 prioritized scenarios	Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	1 (night)
Top 10 prioritized scenarios	Atrium (ground level)	deliberate	accelerant on stacked furniture	1 (night)
Top 10 prioritized scenarios	Eatery	deliberate	accelerant on furniture	1 (night)
Top 10 prioritized scenarios	Common Room with kitchenette	electric blanket or heater	bundle of fabric	1 (night)
Top 10 prioritized scenarios	Kitchen	unattended cooking fire	room lining, or nearby fabric or food/oil	1 (night)
High-consequence, low-probability scenarios with a moderate or high collective probability	Stairway	deliberate	accelerant on room linings or an object brought into the area	1 (night)
Top 10 prioritized scenarios	Apartments	unattended or careless cooking fire	room lining, or nearby fabric or food/oil	1 (night)
Combining the next 2 refined scenarios into 1 worst-case scenario	Atrium (ground level, under the walkway area near the fitness and laundry)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	3
Top 10 prioritized scenarios	Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	3
Top 10 prioritized scenarios	Kitchen	unattended cooking fire	room lining, or nearby fabric or food/oil	3
Top 10 prioritized scenarios & Stakeholder requirement – smouldering fire in a principally occupied room	Apartments (living room)	cigarette	bed clothes/blanket on a sofa	1 (night)
Top 10 prioritized scenarios	Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a smouldering fire)	1 (night)
High-consequence, low-probability scenarios with a moderate or high collective probability & Stakeholder requirement – exposure fire	Outer wall/ cladding	exposure fire	cladding or window breakage	1 (night)
High-consequence, low-probability scenarios with a moderate or high collective probability	Outer wall/ cladding	deliberate	accelerant on rubbish or vehicle against side of building	1 (night)
Stakeholder requirement – concealed fire	Walkways (within wall)	electrical failure	room lining, or electronic equipment	1 (night)
Stakeholder requirement – fire in a structural area	Elevator machine room (roof space)	electrical failure	room linings	1 (night)

A.7.2 Fire-safety design objective of fire fighter life safety

A summary of the highest priority clustered scenarios regarding fire fighter life safety is presented in the following table. The cluster scenario numbers allocated during Task D are used.

Table 43: Refined scenario clusters based on Task E prioritization for the fire-safety design objective of fire fighter life safety

General Priority Level	Cluster No.	Physical Space Description	Cause of Ignition	Materials First Ignited
High	1	Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs
	11	Apartments	unattended or careless cooking fire	room lining, or nearby fabric or food/oil
Moderately High	10	Common Room with kitchenette	electric blanket or heater	bundle of fabric
	13	Apartments	cigarette	bed clothes
	18	Kitchen	unattended cooking fire	room lining, or nearby fabric or food/oil
	2	Atrium (ground level)	deliberate	accelerant on stacked furniture
	20	Eatery	deliberate	accelerant on furniture
	21	Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a smouldering fire)
	24	Elevator lobby	deliberate	accelerant on room linings or an object brought into the area
	25	Stairway	deliberate	accelerant on room linings or an object brought into the area
	32	Outer wall/ cladding	exposure fire	cladding or window breakage
	33	Outer wall/ cladding	deliberate	accelerant on rubbish or vehicle against side of building
	4	Laundry	washer/dryer machine failure	bundle of fabric
	7	Common room with kitchenette	cigarette	bundle of fabric
	19	Eatery	electrical failure or knocked over candle(s)	bundle of fabric or furniture
	15	Apartment	electric blanket or heater	bundle of fabrics

Using the same approach as used for the fire-safety design objective of occupant life safety, the top 10 prioritized scenarios are taken as the initial set of refined scenarios. Then the impact of not including the remaining scenarios is considered and any additional refined clustered scenarios are added to the list. The list of refined scenarios is then compared to stakeholder requirements. Note that the stakeholder requirements will vary between design projects and the people who represent the stakeholders for each project.

The example stakeholder requirements for the objective of fire fighter life safety are:

- Fire in a structural area
- Exposure fire
- Fire blocking an exitway
- Shielded room corner fire
- Deliberate fire in a strategic area

A summary of the refined scenarios with the reasons for inclusion are presented in the following table.

Table 44: Refined scenarios with reasons for inclusion for the fire-safety design objective of fire fighter life safety

Reasons for Inclusion in Refined Scenarios	Physical Space Description	Cause of Ignition	Materials First Ignited
Stakeholder - deliberate fire in a strategic area and Combining the next 2 refined scenarios into 1 worst-case scenario	Atrium (ground level, under the walkway area near the stairs)	deliberate	accelerant on stacked furniture
Top 10 prioritized scenarios	Atrium (ground level)	deliberate	accelerant on stacked furniture
Top 10 prioritized scenarios	Atrium (ground level)	electrical fault igniting	decorations (e.g. Christmas decorations, etc.), or stacked chairs
Top 10 prioritized scenarios and Stakeholder – fire blocking an exitway and Combining the next refined scenario into 1 worst-case scenario	Stairway	deliberate	accelerant on room linings or an object brought into the area
Top 10 prioritized scenarios	Elevator lobby	deliberate	accelerant on room linings or an object brought into the area
Top 10 prioritized scenarios	Common Room with kitchenette (2nd floor)	electric blanket or heater	bundle of fabric
Top 10 prioritized scenarios	Apartments	unattended or careless cooking fire	room lining, or nearby fabric or food/oil
Top 10 prioritized scenarios	Apartments	cigarette	bed clothes
Top 10 prioritized scenarios and Combining the next refined scenario into 1 worst-case scenario	Kitchen	unattended cooking fire	food/oil
Top 10 prioritized scenarios	Eatery	deliberate	accelerant on furniture
Top 10 prioritized scenarios And Stakeholder – shielded room corner fire	Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a shielded room corner fire)
High-consequence, low-probability scenarios with a moderate or high collective probability & Stakeholder requirement – exposure fire	Outer wall/ cladding	exposure fire	cladding or window breakage
Stakeholder requirement – concealed fire	Walkways (within wall)	electrical failure	room lining, or electronic equipment
Stakeholder requirement – fire in a structural area	Elevator machine room (roof space)	electrical failure	room linings

Table Note: Greyed out rows are combined into the scenario directly above them.

A.8 Task G: Qualify scenarios

This is one example of the documented qualitative descriptions of the refined selection of fire-safety scenarios for analysis. The documentation of this section may be presented in a different way. However the documentation will include descriptions of the key model factors and the related assumptions and limitations.

A.8.1 Fire-safety design objective of occupant life safety

Summary of qualitative descriptions of the refined fire-safety scenario suite

Table 45: Summary of fire-safety scenarios for the design objective of occupant life safety

Fire-Safety Scenario No.	Physical Space Description	Cause of Ignition	Materials First Ignited	Building Usage
1	Atrium (ground level, under the walkway area near the stairs)	deliberate	accelerant on stacked furniture	1 (night)
2	Atrium (ground level, under the walkway area near the fitness and laundry)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	3
3	Apartments	unattended or careless cooking fire	room lining, or nearby fabric or food/oil	1 (night)
4	Apartments (living room)	cigarette	bed clothes/blanket on a sofa	1 (night)
5	Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (smouldering to flaming fire)	1 (night)
6	Outer wall/ cladding	exposure fire	cladding or window breakage	1 (night)
7	Outer wall/ cladding	deliberate	accelerant on rubbish or vehicle against side of building	1 (night)
8	Walkways (within wall)	electrical failure	room lining, or electronic equipment	1 (night)
9	Elevator machine room (roof space)	electrical failure	room linings	1 (night)

Fire-safety scenarios or scenario clusters not selected for analysis and associated reasons

Table 46: Summary of scenarios considered but not included in the refined fire safety scenario suite for occupant life safety

Physical Space Description	Cause of Ignition	Materials Ignited	Usage	Reason Not Included
Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	1 (night)	Covered by Scenario 1
			3	Covered by Scenario 2
	deliberate	accelerant on stacked furniture	1 (night)	Covered by Scenario 1
Managemen t office	electrical fault igniting	stored paper during	1 (night)	Scenarios 1 and 2 are worse cases & area has sprinkler, and smoke detector coverage
Laundry	washer/dryer machine failure	bundle of fabric	1 (night)	Covered by Scenario 1 & area has sprinkler, and heat detector coverage
Fitness centre	electrical failure	room lining or bundle of fabric	1 (night)	Scenarios 1 and 2 are worse cases & area has sprinkler, and smoke detector coverage
Common room with kitchenette	electrical failure	room lining, electronic equipment or bundle of fabric	1 (night)	Covered by Scenario 1
	cigarette	bundle of fabric	1 (night)	Scenarios 1 and 4 are similar or worse cases
	deliberate	accelerant on upholstered chairs	1 (night)	Scenarios 1 and 3 are similar or worse cases
	fire play	upholstered chair	1 (night)	Scenarios 1 and 3 are similar or worse cases
	electric blanket or heater	bundle of fabric	1 (night)	Scenarios 1 and 3 are similar or worse cases
Apartments				
	deliberate	accelerant on upholstered furniture	1 (night)	Low likelihood Scenarios 1,
	cigarette	bed clothes	1 (night)	Scenario 4 is similar
	fire play	upholstered sofa	1 (night)	Scenarios 3 and 4 are similar
	electric blanket or heater	bundle of fabrics	1 (night)	Scenarios 3 and 4 are similar
	electrical failure	room lining, or electronic equipment	1 (night)	Scenarios 3 and 4 are similar
Kitchen	unattended cooking fire	room lining, or nearby fabric or food/oil	1 (night)	Scenario 1 is a worse case
			3	Scenario 2 is a worse case
Eatery	electrical failure or knocked over candle(s)	bundle of fabric or furniture	1 (night)	Scenario 1 is a worse case
			3	Scenario 2 is a worse case
	deliberate	accelerant on furniture	1 (night)	Scenario 1 is a similar case
			3	Scenario 2 is a similar case
Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a smouldering fire)	3	Scenario 2 is a worse case
	deliberate	stacked upholstered chairs and tables, etc.	1 (night)	Scenario 1 and 5 are worse cases
	fire play	upholstered chairs or curtains, etc.	1 (night)	Scenario 1 is a worse case
Elevator lobby	deliberate	accelerant on room linings or an object brought into the area	1 (night)	Scenario 1 is a similar case
Stairway	deliberate	accelerant on room linings or an object brought into the area	1 (night)	Scenario 1 is a similar case

Elevator shaft and machine room	deliberate	accelerant on room linings or an object brought into the area	1 (night)	Scenario 1 is a similar case
Carparking (open to air)	deliberate	accelerant on vehicle	1 (night)	Low likelihood, low consequence Protection by distance from building and area is in open air
BBQ area	deliberate	accelerant on stacked outdoor furniture	1 (night)	Low likelihood, low consequence Protection by distance from building and area is in open air
Rubbish area	cigarette	rubbish	1 (night)	Low likelihood, low consequence Protection by distance from building and area is in open air
	deliberate	rubbish	1 (night)	Low likelihood, low consequence Protection by distance from building and area is in open air

Scenario 1

Physical Space Description	Cause of Ignition	Materials First Ignited	Building Usage
Atrium (ground level, under the walkway area near the stairs)	deliberate	accelerant on stacked furniture	1 (night)

Note that directives to aspects described in other Tasks imply that those details would be included in the documentation qualifying the scenarios used to challenge the design.

Table 47: Description of model factors for Scenario 1 for the fire-safety objective of occupant life-safety

Description of Model Factor for Inclusion in the Worked Example	Egress	Fire	Structure
Building Layout	Drawings 1 to 5		
Non-Emergency Environmental Conditions	As described in Task A		
Fire Start			
Potential Fire Hazards/Ignition Sources		Deliberate Ignition using accelerant on stacked furniture	
Location of Ignition	Atrium at ground level, under the edge of the second level walkway in the south-east corner of the room near the stairway		
Relative Time of Day for Event Start	Night		
Population			
Size	As described for Usage 1 in Task A	Calculated during egress modelling	
Location			
Characteristics / Distribution			
Impairments			
Activities/Status		Calculated during egress modelling	
Commitment/Engagement/Habituation			
Language/Cultural			
Social Role/Affiliation			
Familiarity			
Training/Experience			
Visual Access	Calculated during fire modelling	Contents distribution and materials	
Fire & Smoke Development & Spread			
Type of Fire		Flaming	
Distribution and Types of Fuels/Fire Load Density		Stacked chairs at side of room	
Internal Ventilation Conditions		Well-ventilated	
External Environmental Conditions		As described in Task A	
Fire Size		Large	
Criteria for Fire Spread			
Status of Exit Routes, incl. opening/closing doors	Prescribed description of scenario and influenced by results of fire modelling	Prescribed description of scenario and/or calculated during	

		egress modelling	
Building Structure			
Structural Members		-	Drawings 1 to 5, as described in Task A
Structural Loads			
Characteristics of Elements and Connections			
Restraint Conditions			
Thermal & Mechanical Material Properties			
Fire-safety systems, features, strategies, and procedures			
Technical – Detection	Drawings 1 to 5, as described in Task A	Drawings 1 to 5, as described in Task A	
Human – Detection			
Technical – Notification			
Human – Notification			
Human – Evacuation Procedure/ Strategy		Drawings 1 to 5, as described in Task A	
Technical – Compartmentation			Drawings 1 to 5, as described in Task A
Technical – Suppression Systems	Drawings 1 to 5, as described in Task A		
Human – Suppression, incl. Fire Fighting			
Human Response			
Pre-Evacuation	Based on occupant characteristics described in Task A and influenced by results of fire modelling		
Assumed Travel Speeds			
Attainable Speeds			
Route Use		Calculated during egress modelling	
Flow Constraints			

Table Notes:
O – Factor that is considered for the analysis indicated in the column header.
X – Factor that is considered for the analysis, but the factor is calculated during, or influenced by, another type of analysis or the selection of modelling approach.
- – Factor that could be included in an analysis approach but is not included in the approaches selected for this worked example. Note that this is not an exhaustive list of potential model factors.

The fire modelling approach for this scenario has been chosen to utilize field modelling to investigate the smoke and hot gas movement particularly with the spill plume into the atrium and the tenability associated with the walkways around the edges of the atrium and the effectiveness of the fire safety features. Therefore validation and verification of the spill plume aspect of the chosen field modelling package is important for this evaluation of the analysis of this scenario. The fire safety features that will be varied to investigate the potential performance of the design will be primarily the geometry of the atrium and the smoke venting system. The assumptions associated with the type of fire are expected to be influential in the performance of the design. Therefore the sensitivity to fire growth rate and maximum heat release rate will be included in the analysis. Another consideration is the limitations of the interaction between the modelling approaches chosen for fire and egress, in particular how influential are the parameter values that are passed, such as time when particular doors are opened and closed or the tenability conditions that may influence travel speed or to trigger decisions to initiate alternative path finding, etc.

Scenario 2

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A.8.2 Fire-safety design objective of fire fighter life safety

Summary of qualitative descriptions of the refined fire-safety scenario suite

Table 48: Summary of fire-safety scenarios for the design objective of fire fighter life safety

Fire-Safety Scenario No.	Physical Space Description	Cause of Ignition	Materials First Ignited
1	Atrium (ground level, under the walkway area near the stairs)	deliberate	accelerant on stacked furniture
2	Stairway	deliberate	accelerant on room linings or an object brought into the area
3	Common Room with kitchenette (2nd floor)	electric blanket or heater	bundle of fabric
4	Apartments	unattended or careless cooking fire	room lining, or nearby fabric or food/oil
5	Apartments	cigarette	bed clothes
6	Kitchen	unattended cooking fire	food/oil
7	Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a shielded room corner fire)
8	Outer wall/ cladding	exposure fire	cladding or window breakage
9	Walkways (within wall)	electrical failure	room lining, or electronic equipment
10	Elevator machine room (roof space)	electrical failure	room linings

Fire-safety scenarios or scenario clusters not selected for analysis and associated reasons

Table 49: Summary of scenarios considered but not included in the refined fire safety scenario suite for fire fighter life safety

Physical Space Description	Cause of Ignition	Materials First Ignited	Reason Not Included
Atrium (ground level)	electrical fault igniting during the night	decorations (e.g. Christmas decorations, etc.), or stacked chairs	Covered by Scenario 1
Eatery	deliberate	accelerant on furniture	Covered by Scenario 6
Sun room and events area	electrical failure	stacked upholstered chairs and tables, etc. (resulting in a smouldering fire)	Covered by Scenario 7
Elevator lobby	deliberate	accelerant on room linings or an object brought into the area	Scenario 2 is worse case
Laundry	washer/dryer machine failure	bundle of fabric	Scenario 1 is worse case
Common room with kitchenette	cigarette	bundle of fabric	Covered by Scenario 3
Eatery	electrical failure or knocked over candle(s)	bundle of fabric or furniture	Covered by Scenario 6
Apartment	electric blanket or heater	bundle of fabrics	Scenarios 4 and 5 are worse case scenario

Scenario 1

Physical Space Description	Cause of Ignition	Materials First Ignited
Atrium (ground level, under the walkway area near the stairs)	deliberate	accelerant on stacked furniture

Note that directives to aspects described in other Tasks imply that those details would be included in the documentation qualifying the scenarios used to challenge the design.

Table 50: Description of model factors for Scenario 1 for the fire-safety objective of fire fighter life-safety

Description of Model Factor for Inclusion in the Worked Example	Egress	Fire	Structure
Building Layout	-	Drawings 1 to 5	
Non-Emergency Environmental Conditions	-	As described in Task A	
Fire Start			
Potential Fire Hazards/Ignition Sources		Deliberate Ignition using accelerant on stacked furniture	Information extracted from fire modelling results
Location of Ignition	-	Atrium at ground level, under the edge of the second level walkway in the south-east corner of the room near the stairway	
Relative Time of Day for Event Start	-	Assumed peak period of Fire Service call outs	-
Population			
Size	-	-	
Location	-	-	
Characteristics / Distribution	-	-	
Impairments	-		
Activities/Status	-	-	
Commitment/Engagement/Habituation	-		
Language/Cultural	-		
Social Role/Affiliation	-		
Familiarity	-		
Training/Experience	-		
Visual Access	-	-	
Fire & Smoke Development & Spread			
Type of Fire		Flaming	-
Distribution and Types of Fuels/Fire Load Density		Stacked chairs at side of room	-
Internal Ventilation Conditions		Well-ventilated	-
External Environmental Conditions		As described in Task A	
Fire Size		Large	
Criteria for Fire Spread			-
Status of Exit Routes, incl. opening/closing doors	-	Depends on results of fire modelling	
Building Structure			
Structural Members		-	Drawings 1 to 5, as described in Task A
Structural Loads			
Characteristics of Elements and Connections			
Restraint Conditions			

Thermal & Mechanical Material Properties			
Fire-safety systems, features, strategies, and procedures			
Technical – Detection	-	Drawings 1 to 5, as described in Task A	
Human – Detection	-		
Technical – Notification	-		
Human – Notification	-		
Human – Evacuation Procedure/ Strategy	-	Drawings 1 to 5, as described in Task A	
Technical – Compartmentation			-
Technical – Suppression Systems	-		-
Human – Suppression, incl. Fire Fighting	-		-
Human Response			
Pre-Evacuation	-		
Assumed Travel Speeds	-		
Attainable Speeds	-		
Route Use	-	Depends on results from fire modelling	
Flow Constraints	-		

Table Notes:
O – Factor that is considered for the analysis indicated in the column header.
X – Factor that is considered for the analysis, but the factor is calculated during, or influenced by, another type of analysis or the selection of modelling approach.
- – Factor that could be included in an analysis approach but is not included in the approaches selected for this worked example. Note that this is not an exhaustive list of potential model factors.

Since the fire modelling approach has been chosen to be the same as that used for Scenario 1 for occupant life safety, the same limitations apply (except for those associated with interaction with the chosen egress modelling approach). In the case of the objective being fire fighter life safety the influence of parameter values and assumptions on the building conditions are of interest toward the end of the time considered for occupant life safety, continuing on. Therefore in addition to the sensitivity analysis already discussed, it is important to also identify the parameters that lead to the quickening of the onset of unacceptable conditions for the design as the duration of the scenario increases.

<u>Scenario 2</u>

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A.9 Task H: Quantify scenarios

Select the appropriate available modelling approach and quantify the design fire-safety scenarios for input into relevant model. Document the assumptions and limitations associated with the values chosen for the key model factors.
Finding appropriate data for key model factors may be a significant limitation in this process. The implications of these limitations must also be incorporated into the analysis of modelled outcomes. Therefore this must be taken into account early in the process, as described in Task C1.1.
Values to be used in the quantification of scenarios are dependent on the defined problem, objectives and modelling approach and are not discussed here.
It is expected that when the example building design presented is this example is challenged with the design fire scenarios, changes will be required to this design in order to meet the acceptance criteria. It is expected that these design changes and repeating the challenge with the suite of design fires will be iterative. Design changes in order to meet the acceptance criteria for one design fire scenario must be checked by challenging the new design with the remainder of the suite of design fire scenarios.
For this example, some of the building spaces that would be particularly taken into consideration in terms of the appropriateness of fire safety features for building performance that might need to be changed under particular Scenarios include:

- The stairway that currently surrounds the elevator and lobby. This may need to be a ramp, or other potential solution.
- The pedestrian areas of the outside balconies and ramp that are adjacent to apartment windows may need protection of a deluge sprinkler system.
- The natural venting system of the atrium might need to be upgraded to a mechanical extract system.
- Ramps may need to be re-designed to in terms of the maximum rise of a ramp and minimum size of landings to ensure accessibility.
- Etc.

The final design is one which meets the acceptance criteria for all design fire scenarios.

A.10 References

A.10.1 Standards

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