**COMMENTS**

**TO**

**AUSTRALIAN BUILDING CODES BOARD**

**March 2018**

# RESPONSE 1(b)

# NCC 2019

# Fire Safety in Class 2 and Class 3 residential buildings


PROVIDED BY:

**ENABLING BUILT ENVIRONMENT PROGRAM**

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# 1. Structure of Response

The basis of the PFC is not clear although the reasoning can be gathered from reading between the lines. It is interesting to note that this PFC still does not address the greatest risk which is in the home. Should anyone wish to install an active sprinkler system to their home are heavily penalised through the exorbitant requirements of water supply authorities and the like. This may not be the province of the NCC but nevertheless it is still an issue and Part 2 of the NCC could provide some relief given that there has been extensive work carried out by BRANZ on this issue.

The structure of our response is therefore naturally concerned with promoting life safety in Class 2 and 3 buildings via a cost effective active protection solution, but adding to this that the approach should be extended through to Class 1 buildings. The structure is as follows;

- Section 2 – Introduction
- Section 3 – The Proposal
  - 3.1 Generally
  - 3.2 Occupant Needs
  - 3.3 Option Performance
- Section 4 – The Real Opportunity
  - 4.1 The efficacy of the PFC
  - 4.2 Creating a level playing field – the Health issue
  - 4.3 Alternative viable options
- Section 5 – Conclusion

**DOES THE PFC ADRESS THE REAL NEED OR CREATE AN ADDITIONAL OPPORTUNITY?**

# 2. Introduction

Firstly the overall PFC is a move in a very necessary direction. It is good to see cost effectiveness with life safety as the baseline measure driving the proposal.

Before commenting any further it is necessary to find out what cost-effective solutions[1] actually mean. Schittich (2007) makes an extremely important point in terms of cost effectiveness;

*"Cost efficiency is not the same as cheap building; but it must not by definition be a disadvantage. Often doing away with a multitude of superfluous elements can lead to a more ….credible solution. ……cost efficient building usually means an increase in concerted effort….."*

The PFC does offer a cost effective solution in terms of the concessions[2] offered for travel distances, distances between exits, FRL's and the like. The examples provided show the impact on apartment footprints and there is no doubt that the resultant savings in construction cost together with the reduction in risk of 72% for Option 3, as illustrated in Figure 1 of the PFC on page 14, should motivate the market. Option 3 also more closely matches the definition of cost effectiveness[1] . The approach creates an opportunity to address the high risk of fire related fatalities and injuries in the dwelling unit which is a term that relates to the residential living space and not the form in which it is provided. The difference is a function of "density" and will be satisfied by apartments for the higher densities through to detached housing for the lower densities. At present Class 1 buildings are excluded due to the fact that the only fire protection requirements are passive and the level of risk has been dispensed with due to the rights of the home owner being responsible for their own protection. This has unfortunate repercussions for older persons who may wish to age in place i.e. either remaining in their own houses or in the same area downsizing to apartments. The cost to provide the same level of life safety as that of Option 3 is now less exaggerated than before the PFC but is still exorbitant for detached housing in terms of the unit cost per dwelling unit. This is mainly due to the requirements of water supply

[1] Schittich C, (2007) Cost and quality awareness in building a challenge in eds. Schittich C, Cost-Effective Building: Economic concepts and constructions, Redakton DETAIL, pp. 9-11.

[2] See Table 1 PFC Document, on page 9.

authorities for the installation of backflow prevention valves or similar[3]. This issue will be discussed in Section 4.

*Figure 1 – Class 2 Building less than 25m in height.*
*(Source: Meriton Marketing Brochure for "Dahlia – Pagewood Green" Apartments.*

Internal floor areas for the development in Figure 1 are:

1 bedroom + study 63m$^2$ – 73m$^2$

2 bedroom 76m$^2$ – 91m$^2$

2 bedroom + study 83m$^2$ – 102m$^2$

3 bedroom 108m$^2$ – 115m$^2$

3 bedroom + study 109m$^2$ – 133m$^2$

In terms of dwelling unit floor areas 80.8% of downsizers[4] lived in dwelling units with floor areas up to 199m$^2$ with 34.6% of them living in dwelling units of between 100-149m$^2$. Apartments are now coming on to the market with floor areas within the 100-149m$^2$ range as demonstrated in Figure 1 and the associated floor area schedule above. An analysis indicates that the additional capital cost of adopting a system in terms of protection reliability compared to Options 2 and 3 for a detached dwelling unit as compared to an apartment of a similar area could be as much as $4,500. When one considers the ownership profile as shown in Figure 2 then this is a substantial cost based on their sources of income.

Given the growth of persons over the age of 65 years as demonstrated in Figure 6[5] projected to the year 2030 it would appear that apartments may be available in the same inner CBD areas as detached housing with similar layouts (no. of bedrooms and floor area) as demonstrated in Figure 3[4]. The apartments will be accessible in that most would be provided with lifts.

[3] MacLennan (2016) *Fire Safety and Independent Living – A conundrum or not?* Proceedings of the 6th International Conference for Universal Design, Nagoya, 2016, (CD)/proceedings/papers_pdf/OP-002.pdf. See also Soja E, and Edwards APR, (2006), *Domestic Fire Sprinkler Systems – Report on Water Quality, Reliability and Application to Other Property*, BRANZ, Report No. FQ5011, New Zealand.

[4] Judd, B., Liu, E., Easthope, H., Davy, L. and Bridge, C. (2014) *Downsizing amongst older Australians*, AHURI Final Report No.214. Melbourne: Australian Housing and Urban Research Institute.

[5] MacLennan HA,

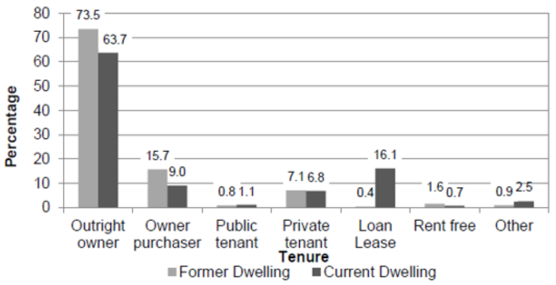


*Figure 2: Tenure of Dwelling Unit Ownership - Downsizers*

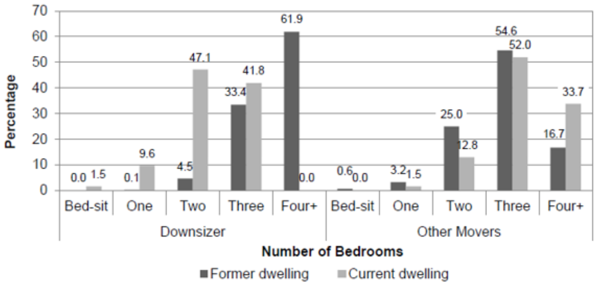


*Figure 3: Number of Bedrooms - Downsizers*

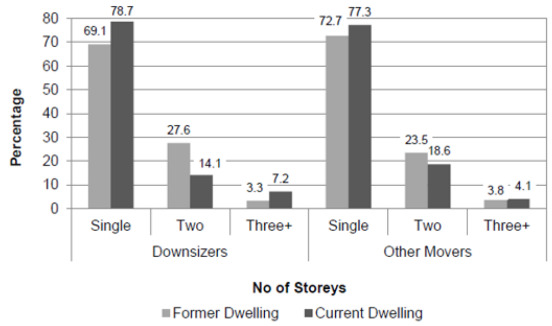


*Figure 4: No. of Storeys – Downsizers*

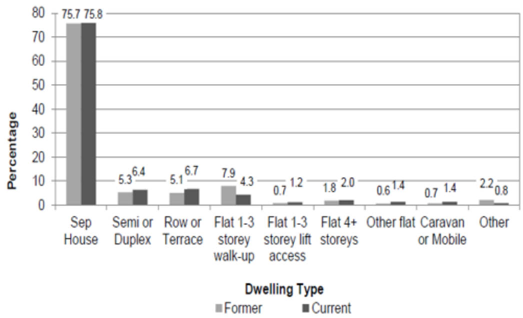


*Figure 5: Dwelling Type - Downsizers*

*Source for Figures 2-5: Judd, B., Liu, E., Easthope, H., Davy, L. and Bridge, C. (2014) Downsizing amongst older Australians, AHURI Final Report No.214. Melbourne: Australian Housing and Urban Research Institute.*

The PFC, if adopted, will provide the opportunity for the provision of downsizing opportunities for those over the age of 65 years with a level of life safety suited to their needs as they age. It would be appropriate for this level of protection to be available, as discussed above for Class 1 buildings in terms of the removal of the additional burden of water supply compliance and other requirements that apply to attached accommodation as that discussed by MacLennan (2016)[3].

# 3. The Proposal

## 3.1 Generally

The most all-encompassing "picture" of the need for "residential sprinklers" may be found in the ABS population statistics projected to the year 2030 as presented in Figure 6 where apartments could be promoted as a downsizing proposition for those occupants over the age of 65 years. Two comprehensive studies being Miller and Davey (2007) and Xiong, Bruck and Ball (2016), clearly indicate the risk of not surviving a fire as being related to age and the associated functional limitations[6]. **Table 1** below shows the fatality rate shows that age alone is the fourth main characteristic of victims. Other more relevant characteristics in order of importance are drug intake, discarded cigarettes, and living alone, all of which are relevant factors for the +65 year age group. See section 4 for further discussion.

[6]Xiong L, Bruck D and Ball M, (2016), (Preventing accidental residential fires; the role of human involvement in non-injury house fires, Fire and Materials, published in Wiley Online Library DOI: 10.1002/fam2356.) and Miller and Davey (2007) (The Risks Perceptions and Experiences of Fire Among Older People, Report for NZ Institute for Research on Ageing, Heimdall Consulting Ltd.) also confirm these statements by reference to international research from the UK, Japan, USA, as well as numerous Australasian Studies such as Rhodes and Reinhold (1998), Brennan and Thomas (2001), Duncanson et al (2001-2002) and Zhang et al (2006). The Australasian research continued on with an extensive study by Barnett (2008) relating to fire risk and elder residents. This study was similar to Miller and Davey (2007) in some ways but far more extensive.

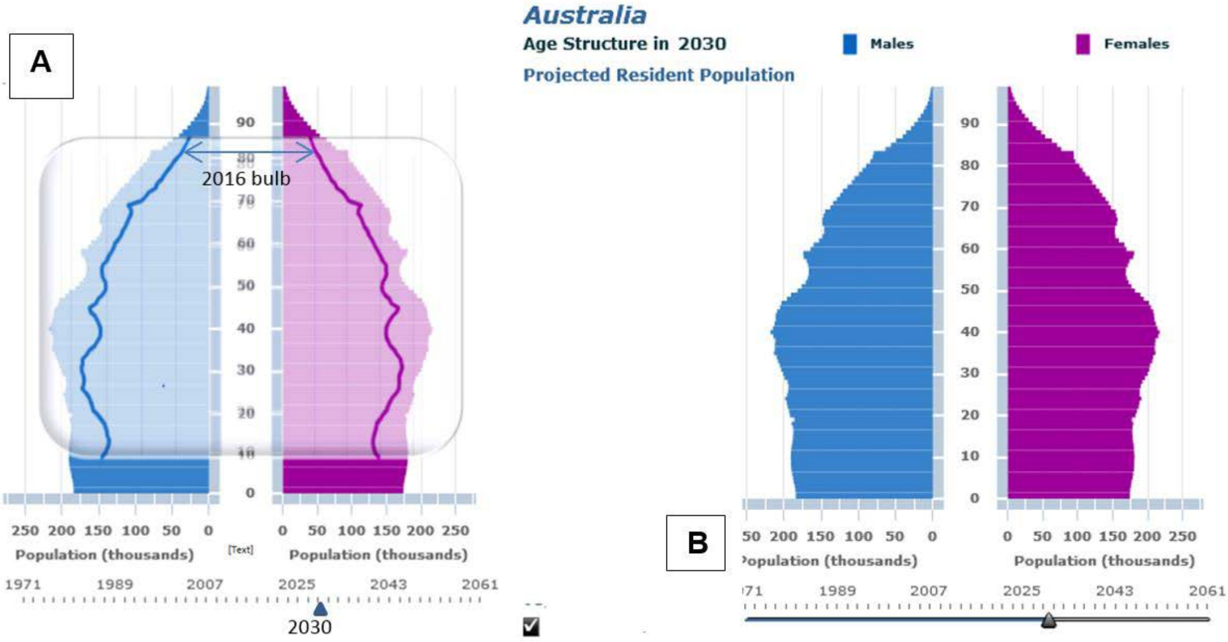


***Figure 6 A: Baby Boomers = 70 yrs of age in 2016 – start of the "bulge"; (B) Baby boomer bulge in 2030.***

*Table 1: **Number of Deaths / 100,000 Population – Comparison Australia / New Zealand***

| **Unintentional Injury/Deaths from House Fires Rates per 100,000 population** | | |
|---|---|---|
| Age Group | Rate of deaths / 100,000 population | |
| | Australia | New Zealand |
| 0-4 | 1.6 | - |
| 5-9 | 0.5 | - |
| 10-14 | - | - |
| 15-19 | 0.6 | - |
| 20-24 | 0.4 | - |
| 25-29 | - | - |
| 30-34 | 0.4 | - |
| 35-39 | 0.5 | - |
| 40-44 | 0.5 | - |
| 45-49 | 0.5 | - |
| 50-54 | 0.8 | - |
| 55-59 | 0.7 | - |
| 60-64 | 1 | - |
| 65-69 | 1.1 | 0.6 |
| 70-74 | 1.6 | 0.6 |
| 75-79 | 2 | 1.8 |
| 80-84 | 3.3 | 1.8 |
| 85+ | 4.6 | 4.4 |

Given that ageing will continue to be an issue the PFC does address some of the issues raised by AFAC in 2015 in Submission No. 5 to the Senate Standing Committee on Legal and Constitutional Affairs – "Inquiry into use of smoke alarms to prevent smoke and fire related deaths" which were based on the results of research carried out by Fire and Rescue NSW.

This PFC is therefore welcome and constructive. There are some comments that EBEP need to make regarding the risk associated with Options 2 and 3 in terms of the basis of evidence of occupant response.

## 3.2 Occupant Needs

No doubt the series of Fire Tests referred to in the EFT 2575 Report and carried out by the CSIRO, formed the basis of the sprinkler tests which could be used to establish ASET. We are concerned, however, about the observations of the SOU layouts for two reasons;

- Origin and time of the fire and the onset of untenable conditions especially in terms of visibility in relation of the front door of the SOU directly associated with the type of furnishings and the room layout. MacLennan (2016) analysed many typical room layouts for both houses and apartments and highlighted the use of open planning[8].
- Time of the fire which would dictate the state of the occupant and their likely location.

Although a study of residential fires between 1974 and 2005 was associated with houses[7] the findings can be extended to apartments especially given the possible trend to larger apartments as a downsizing option in Figure 1 and the similarity in layouts between the two dwelling unit types as mirrored in Figure 3 and MacLennan (2016)[3]. The study showed the distribution of the rooms of fire origin as follows;

- 40.6% in kitchen which is even more prevalent now given that most new homes are now open plan
- 21.9% in the bedroom
- 11.5% in the lounge or 13.8% in lounge/dining areas

The impact of open planning[8] on the above is that if the room of fire origin is taken as the kitchen/dining/living room then 54.4% of the incidents would be between the bedrooms and the front door.

Sprinklers may be installed but the needs of the occupants when they are located in the bedroom, asleep, relate to the time they are informed about the fire and the signature of the signal (smoke alarm) each of which will determine the waking effectiveness of the detection device. Thomas and Bruck (2009) in a study for the ABCB showed that a 520Hz square wave signature smoke detector/alarm was the most effective signature and that it aroused 95.5% of the population[9]. This rate can be increased further with the addition of a “pillow shaker”[10]. The associated smoke detector most likely needs to be a photo-optical type.

Consult MacLennan (2016) attached to this submission for reference to occupant characteristics but he did indicate that non-robotic egress studies have shown that the time taken by an occupant to safely evacuate a house which could also include an apartment SOU could vary by 827%. A suitable sprinkler system will most likely prevent the occurrence of flashover but this will be a function of sprinkler coverage.

## 3.3 Option Performance

There are two residential sprinkler options put forward shown in Figures 7 and 8 below

[7] Australian Fire and Emergency Service Authorities Council (2009) Accidental Fire Injuries in Residential Structures: Who’s at Risk, AFAC, Section 9.
[8] See also Fraser-Mitchell J and Williams C, (2009), Open flat layouts; Assessing life safety in the event of fire, NHBC Foundation.
[9] Bruck D, and Thomas I, (2009), Towards a Better Smoke Alarm Signal – an Evidence Based Approach, in the Fire Safety Science Proceedings of the Ninth International Symposium pp.403-414.
[10] See Summary Bulletin on Smoke Alarms in HMInfo Pack available at http://www.homemods.info/publications-by-hminfo/summary/summary-bulletin-fire-safety-smoke-alarms

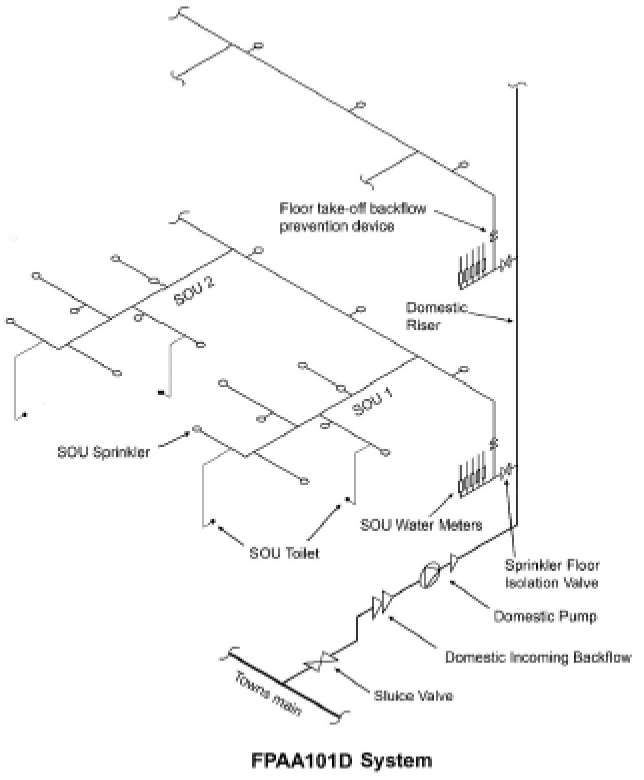


Figure 7: Option 2 – Fed from the Domestic Water System
(Adaptation of AS2118.5)

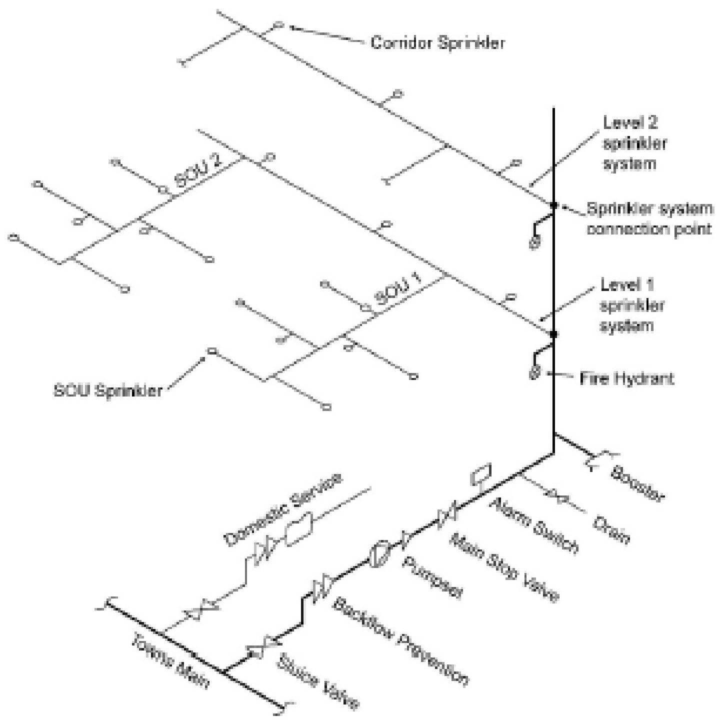


Figure 8: Option 3 – Fed from Hydrant System
(FPAA101H)

FPAA 101D (Option 2) excludes sprinkler protection of the following low risk areas:

(a) Throughout the building

(i) Concealed floor, ceiling and roof spaces not used as living areas.

(ii) Toilets, bathrooms and ensuites, excluding dual use as a laundry.

**(b) Within SOUs only**:

(i) Hallways, entries, stairs and the like not exceeding 1.5m in width.

(ii) Cupboards, wardrobes, walk-in wardrobes, pantries, alcoves and recesses less than 3.0 $m^2$; not containing clothes driers, gas water heaters, cooking appliances and the like, or used for the storage of flammable liquids.

(iii) Small architectural features such as planter box windows and bay windows.

Option 3 provides full coverage within the SOU and elsewhere. We are concerned with the analysis provided in Appendix B which implies via the comments of Wood[11] that Option 2 is superior to Option 3 in some regards. The exclusion of some SOU areas from the installation of sprinklers appear to have originated historically from NFPA practice.

An evidence based study of apartment occupant use and layouts could quite well alter the risk profile of Option 2 especially in terms of potential occupant injuries and fatalities. It would be interesting to “drill down” into the statistics similar to those referred to in Figure 22 of Appendix D of the EFT Report to determine whether there was any correlation between the layout and the “fire risk” (due to occupant use and habits) and fatalities[12] . MacLennan (2016) did this to a certain extent for all residential fires and taking into account the “age” of the SOU and functional limitations of the occupants. This analysis could cast a doubt on the assumptions relating to the classification of low risk areas, especially passages up to 1500mm wide.

The risk analysis outlined in the ETF Report is summarised in Figure 9 below;

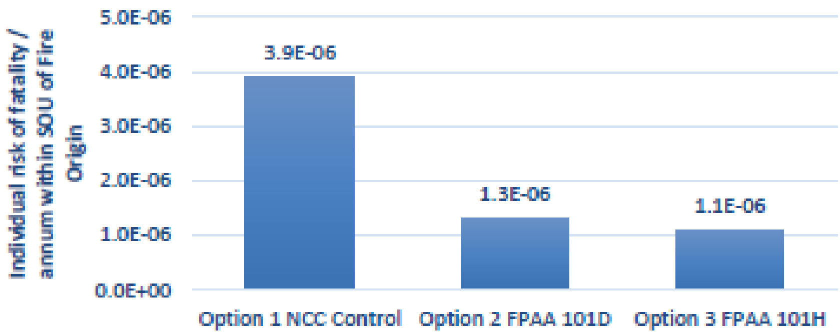


Figure 9: Level of Risk within each apartment or SOU (See Figure 8 for Schematics of Options 2 and 3).

Our overall interest in the PFC is the dramatic reduction in risk of occupant fatality in fires as demonstrated in Figure 9 above given that over 40% of all fires occur in residential occupancies[13].

In terms of performance:

[11] Wood, D., *Reliability of Water Supply Review*. 2017, Liquid Hydraulics: NSW.
[12] See also Kerber (2012) *Analysis of Changing Residential Fire Dynamics and its implications on operational firefighter timeframes*, Underwriter’s Laboratories, US.
[13] Refer to MacLennan (2016)[3]

- Option 3 appears to be the most cost effective where fire hydrants are required in that all areas within the SOU are protected. The level of risk is 3.5 times less than that currently offered.
- Option 2 results in an increase of occupant risk of some 20%. This finding is doubtful for the reasons set down in Section 3.2 of this submission.
- Option 1 provides the baseline where the level of risk is 3-3.5 times of a sprinklered alternative.

Within an SOU for all options it is required to comply with the minimum NCC deemed-to satisfy provisions and other key parameters will be similar for all three options including

- the fire hazard properties of wall and ceiling linings and flooring
- the detection and alarm system
- internal layouts of SOUs and contents
- number of occupants within an SOU

The current NCC DtS requirements set down the provision of a hard wired smoke detection/alarm system to provide early warning to the occupants. It should be noted that the smoke detectors may not be able to awaken all occupants from their sleep as explained in Section 3.2 of this submission[9].

The ability of sprinklers to control and/or suppress fires in SOU's exceed 80% as set out in the EFT Report. These levels are also corroborated by New Zealand and US studies as noted in the Report and verified by the writer. The time available for egress out of the apartment will allow for the full variation in escape times as discussed by MacLennan (2016)[3]. Over 80% of the time we can conclude that the occupants most likely have been "protected in place". This corresponds with 97% of all residential fires being confined to the room of fire origin.

# 4. The real opportunity

## 4.1 The efficacy of the PFC

The efficacy of the residential sprinklers show that there is "defend in place potential". This is shown by the EFT Report and MacLennan (2016)[3]. In terms of dwelling unit floor areas 80.8% of downsizers[14] (i.e. mainly older persons) lived in dwelling units with floor areas up to 199m$^2$ with 34.6% of them living in dwelling units of between 100-149m$^2$. Apartments are now coming on to the market with floor areas within the 100-149m$^2$ range as demonstrated in Figure 1 and the associated floor area schedule below. An analysis indicates that the additional capital cost of adopting a system in terms of protection reliability compared to Options 2 and 3 for a detached dwelling unit as compared to an apartment of a similar area could be as much as $4,500+. When one considers the ownership profile as shown in Figure 2 then this is a substantial cost based on their sources of income.

*Table 2: Schedule of Apartment Areas*

| |
|---|
| 1 bedroom + study 63m$^2$ – 73m$^2$ |
| 2 bedroom 76m$^2$ – 91m$^2$ |
| 2 bedroom + study 83m$^2$ – 102m$^2$ |
| 3 bedroom 108m$^2$ – 115m$^2$ |
| 3 bedroom + study 109m$^2$ – 133m$^2$ |

[14] Judd, B., Liu, E., Easthope, H., Davy, L. and Bridge, C. (2014) *Downsizing amongst older Australians*, AHURI Final Report No.214. Melbourne: Australian Housing and Urban Research Institute.

## 4.2 Creating a level playing field – the health issue

Two comprehensive studies being Miller and Davey (2007) and Xiong, Bruck and Ball (2016)[6], clearly indicate the risk of not surviving a fire as being related to age and the associated functional limitations **Table1** above shows that age alone is the fourth main characteristic of victims of fire. Other more relevant characteristics in order of importance are drug intake, discarded cigarettes, and living alone, all of which are relevant factors for the +65 year age group. Table 1 also shows that small children between the ages of 0-4 years are 4 times more likely to be a fatality in a fire than their parents.

Age also has a major impact on moving around a building as indicated by the Occupant Characterisation Model being developed for the DV2 Access Verification Handbook by ABCB and EBEP in Appendix A. This also relates to response.

The characterisation model referred to above will show that the response, decision-making and movement abilities of older persons most likely will result in a significant group not being able to survive the onset of untenable conditions in a fire as demonstrated by Xiong et al (2016)[6] and MacLennan (2016)[3]. Egress times to outside the house according to Proulx et al (2006)[15] could be as much as 660 seconds. An extensive study by Kerber (2012)[16] showed that with modern furnishings and a detection/alarm time of 120 seconds that Fire Services took 360 seconds (6 minutes) to travel from the Station to the Fire Incident Site. Kerber (2012) also showed that the time taken for conditions to become untenable can be as little as 120s.

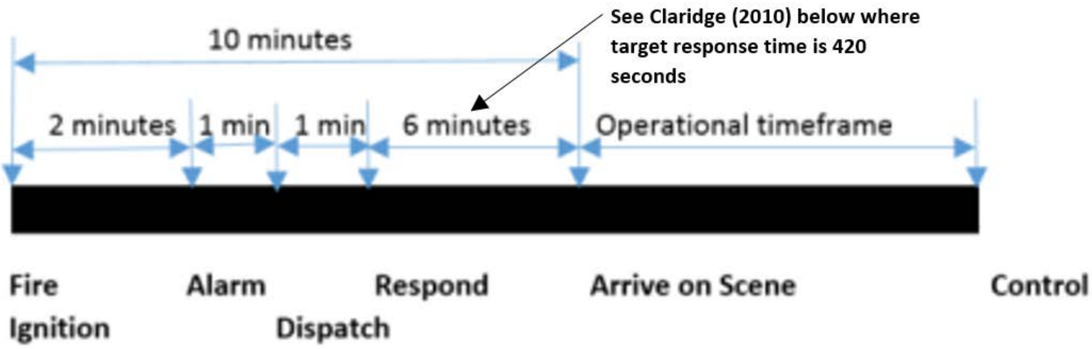


Figure 10: Fire Service Response Timeline – Kerber (2012)

* See Study by Claridge E, (2010) *Assessment and Validation of the Fire Brigade Intervention Model for use within New Zealand and Performance-Based Fire Engineering*, Fire Engineering Research Report 10/4, University of Canterbury.

Given the growth of persons over the age of 65 years as demonstrated in Figure 6[17] projected to the year 2030 it would appear that with RSET calculated in accordance with Section 5.6 of the proposed **fire verification method,** being 330s + (60 -120s) for alarm activation and notification, the Fire Service would still not have turned out/ arrived. Active protection systems similar to and as reliable as Option 3 sprinklers would automatically extend the ASET well beyond 120s. Seeing 40% of all fatalities occur in detached dwelling unit fires and the ageing population will continue to grow as illustrated in Figures 6A and 6B there is a real opportunity to promote a cost effective Class 1a and 1b active fire protection system which will reliably protect life and also provide the appropriate impetus to ageing in place.

The option 2 sprinkler solution could be considered but there will still be cost penalties in terms of water supply and other items. This is discussed further in Section 4.3 below.

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[15] Table 2 of Proulx, Cavan and Tonikian (2006) *Egress times from single family houses*, IRC Report IRC-RR-209.

[16] Kerber S, (2012), Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes, Underwriter's Laboratories, US

[17] MacLennan HA, (2016) Figure 2 utilising ABS Data

## 4.3 Alternative viable solutions

### 4.3.1 Challenges

Funding agencies, designers and contractors will most likely prefer systems which are called up in an Australian Standard or some other "reputable" document. At present AS2118.5 is an example of such a document. There is a NZ equivalent being NZS 4517. Soja and Edwards (2006)[18] demonstrated that the additional "Authority" requirements may be too onerous in terms of the "perceived" risks associated with water quality and the like.

Research carried out by BRE Global resulted in the development of their **Personal Protection System (watermist)** for use in Class 1 buildings for vulnerable occupants or where downsizing considerations offer alternatives for ageing in place. A handbook was developed for this system being LPS1655. These type of systems are available in Australia.

### 4.3.2 Residential Sprinklers

The Soja and Edwards (2006) study was extended into Australia and the finding altered slightly due to additional factors such as Water Supply Authority requirements re water quality and other related factors. AFAC recommended the solution developed in the BRANZ Study subject to the additional factors raised for targeted use with vulnerable or at risk occupants[19]. The BRANZ Study concluded;

- It is feasible for a combined home plumbing and fire sprinkler system into a new three bedroom Australian home.
- The estimated cost per life saved for a combined sprinkler and plumbing system is sensitive to a number of factors. The Study suggested that such a system may be vital for targeted use with vulnerable at risk communities.
- A Code of Practice needs to be developed for its overall use.

Australian Standard AS 2118 Part 5: 2008 advocates a combined system which is seen as being cost effective. The requirements are still subject to the requirements of the Water Supply Authorities and the domestic water supply infrastructure especially in terms of water supply pressure in each residential area. It is interesting to note that Soja and Edwards in a Report on Water Quality and Domestic Sprinklers[18] found;

"*Microbial and chemical water potability tests were performed on a domestic fire sprinkler system over a period of 12 months. It was found that the microbial quality would not be hazardous to health where range pipe dead legs were up to 4.5m long for a water supply of equal or better quality used in this research. From this it is recommended that dead legs up to 3m could be used in Combination Domestic Fire Sprinkler Systems"*

This finding could be discussed with the relevant Water Supply Authority and imposed as a design constraint on a system complying with either AS2118:5 – 2010 or NZS 4517: 2010 and a proposal put forward for the possible deletion of backflow prevention devices thus saving further costs. This may be a complex issue to resolve. Alternatively there is an alternative solution available using a small water storage tank with a small pump. The tank capacity is based on a duration of supply of 10 minutes minimum. Based on research into the reliability of sprinklers to control the fire being 95% a 10 minute capacity is in order. The above solution still involves the use of a fully compliant interconnected smoke alarm system.

Even with a fully compliant smoke alarm system there is still the issue of the waking effectiveness of the standard smoke alarm sound/ signal signature.

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[18] Soja E and Edwards APR, (2006), *Domestic Sprinkler Systems – Report on Water Quality, Reliability and Application to Other Property*, BRANZ Report FQ5011, New Zealand.

[19] AFAC Submission No. 5 to the Senate Standing Committee on Legal and Constitutional Affairs – "Inquiry into use of smoke alarms to prevent smoke and fire related deaths", August 2015. AFAC (an organisation representing all Fire Brigades and Emergency Services Organisations throughout Australasia) based their view on research carried out by Fire and Rescue NSW in 2005 and full scale room fire testing by CSIRO in 1999.

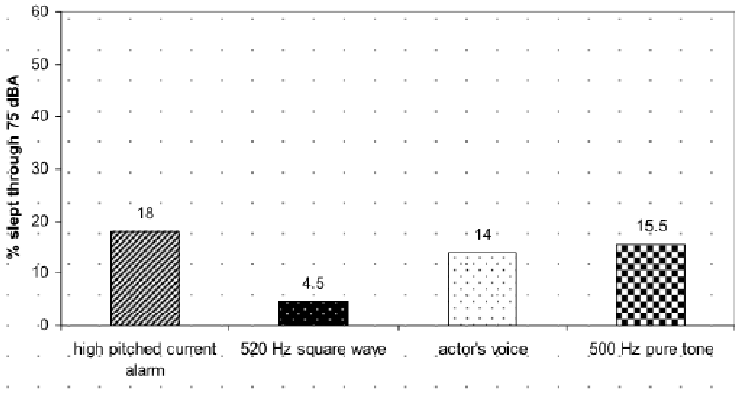


Figure 11: Comparison of Smoke Alarm Response[9]

Bruck and Thomas (2009)[9] demonstrated via an evidenced based "sleep" study that the 520Hz square wave signal resulted in a waking effectiveness of 95.5%. This type of reliability is not mirrored in the Fire Verification Handbook. It should not, however result in any additional cost.

There is a way forward for residential sprinklers.

### 4.3.3 Residential Water Mist (LPS 1655)

LPS 1655[20] is a UK Code of Practice developed by BRE Global. The associated smoke/ heat detection system would be required to comply with NCC Volume 2 Requirements and there is the opportunity to increase the detection reliability. This system could also be used in Class 1b buildings with up to 6 occupants.

Results of tests carried out by Exova Warrington in 2015[21] are extremely interesting;

*Table 3: **Results of Tests carried out by Exova Warrington on 1/7, 23/7 and 27/7 of 2015***

| **Thermocouple location** | **Maximum temperature ($^0$C)** | | | |
|---|---|---|---|---|
| | **Test 1 No suppression** | **Test 2 Centre of Room** | **Test 3 Centre of Room** | **Test 4 Centre with ventilation** |
| **75mm below ceiling** | 799 | 365 | 172 | 164 |
| **1600mm above floor furthest from fire** | 233 | 128 | 51 | 100 |
| **1600mm above floor closest to fire** | 227 | 58 | 39 | 42 |

The "Plumis" Handbook[22] concludes from the results in Table 3

""*In the event of fire, the system is triggered automatically by the appropriate **heat alarm**[23] or a fire panel output. ….Unlike conventional sprinklers Automist can be stopped manually by pressing a button on its control panel or by cutting power…..As Automist uses much less water than a traditional sprinkler system…………Once triggered, a pump drives mains water through the unique nozzle unit, quickly filling the room with a dense fog. Water mist removes heat and displaces oxygen from the fire zone resulting in fire control…suppression. ……..increasing survivability. Adding water to a chip pan fire can greatly exacerbate the fire…..not true for water mist……The water mist technology has benefits for suppressing a greater range of fire scenarios, particularly fires that are shielded from the nozzle release point".*

[20] LPS 1655 Personal Protection Water Mist Systems. A minimum installation would be the provision of heads to the Kitchen, Living/ Dining and Bedrooms (only those occupied by the Vulnerable Resident as a minimum). Also consult Automist Fixed Wall Head Handbook by Plumis Ltd (2015).

[21] Exova Warrington Test Report, Ad-hoc test on water mist systems utilising the principles of the procedure defined in Draft BS8458: 2014: Annex B (ref. 356142).

[22] Automist Fixed Wall Head Handbook V. 1.0.1 (2015), Plumis Ltd.

[23] Fully compliant smoke detection system as required by NCC with possibility of substituting heat detector in the kitchen area.

The Personal Protection System can be used throughout the house or in targeted locations that correspond with the use of the house by the occupants. The attached paper (MacLennan, 2016) provides an example based on the findings from the AFAC Report[24].

### 4.3.4 Conclusion

The current requirements of the National Construction Code 2016 for Class 1a (single houses) and 1b buildings (shared accommodation with a suggested cap of 6 persons). The needs of the residents should be inclusively considered and to this end the concerns of the Australian State Fire and Emergency Services and the implications of the Research shown in this Submission where the time taken to reach non survivable fire conditions can be as little as two minutes need to be addressed. We may conclude that the installation of smoke alarms on their own may not provide the level of protection required to match the limited evacuation capability of the residents. We recommend that the ABCB investigate the possibility of developing a handbook providing guidance to those organisations and occupants who may wish to increase the level of fire safety for vulnerable occupants either via a cost effective residential sprinkler system which overcomes the water supply issues or a water mist system equal to that developed by BRE Global as mirrored in LPS 1655.

## 5. Conclusion

**EBEP in principle supports the PFC for residential sprinklers in Class 2 and 3 buildings under 25m in height except that our analysis has shown that Option 3 is the most appropriate solution both in terms of cost and occupant characteristics and need (especially in terms of layout[8] and use).**

[24] AFAC, (2009), *Accidental Fire Injuries in Residential Structures: Who's at Risk?* Australasian Fire Emergency Service Council, July, 2009.

# APPENDIX

INTERNATIONAL CONFERENCE PAPER BY MACLENNAN (2016)

**Note:** Footnote, Figures, Tables, etc. – numbering isolated to this Appendix and does not continue on from the main submission.

## Fire Safety and Independent Living – A Conundrum or not?

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### ABSTRACT

Over the last 30 years furnishing materials have changed along with the amount of open planning so that in event of fire the time to reach non-survivable conditions can be as little as 120 seconds. Residents depending on their capability to respond and escape may require as much as 660+ seconds to do so. Fire Brigades cannot respond within 120 seconds so what do we do? The provision of smoke alarms may not solve the conundrum in terms of the elderly with dementia. Research shows that ageing in place is a viable proposition for governments and the older resident. It assures a certain degree of independence. The cost of life safety to which these residents have a right is often exaggerated defeating the advantages of older persons remaining in their own homes. Inclusive fire protection systems are available such as water mist but are not gaining traction although they can be retrofitted with ease. This paper addresses the overall conundrum which to date has been ignored for a number of reasons. There is an answer.

### Keywords

Inclusiveness, Safety, Design, Assisted Escape, Targeted assistance.

## 1.0 INTRODUCTION

Hall (2004) asks an extremely relevant question pertaining to fire safety in housing, “How many of the recorded US home fire deaths and injuries were people who could have avoided harm if they had more time to escape?” Hall’s analysis indicates that approximately fifty percent of the deaths and 60% of the injuries could have been prevented one way or another. Care needs to be taken here with those residents who were asleep or who were unable to evacuate unaided as a mere extension of the egress time may not have changed the outcome. Xiong, Bruck and Ball (2016) compared survival and fatality risk factors in accidental house fires and found a difference a strong relationship between location and a resident’s activity at the time of the fire. The resident’s functional limitation or evacuation “ability” also played an important part. These factors when aggregated as shown in **Table 1** below:

***Table 1: Comparison of Fatality and Survivability factors for residents of house fires***

| Factors in fatal accidental house fires (OR>10) |
|---|
| Drug intake |
| Discarded cigarettes |
| Living alone |
| Age > 70 years |
| Asleep at time of fire |
| Located in room of fire origin at ignition |
| Fire originating from cooking on stove |
| Alcohol intake |

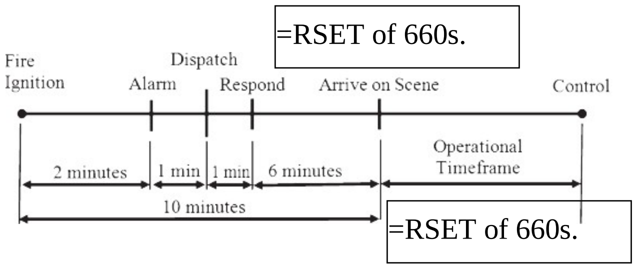
The results also show up an important finding and that is that most fatal fires are associated with residents who have functional limitations resulting from some kind of cognitive and physical impairment. This finding is also supported by an earlier Australasian study of risks, perceptions of fire among older people (>65 years) (Miller and Davey, 2007).

Hall (2010) mentions RSET (required safe escape time) as comprising occupant characteristics and associated escape ability and the contribution that could be made by extending the time available forescape through some kind of intervention. The inference is that extending the time available via the installation of smoke alarms, passive fire separations, additional exits and increasing awareness can only go so far. Some occupants or residents need the fire to be brought under control with tenable conditions until the Fire Brigade (Service) can effect rescue. Proulx et al (2006) examined the activities involved in responding to and escaping a fire relating to occupant characteristics and concluded that most vulnerable residents would require 660 seconds plus to evacuate. It is most likely that the Fire Brigade (Service) would have responded within this time, but it is highly unlikely that most residents who had not escaped within this time frame would have survived. In fact AFAC in their submission to the Senate Standing Committee on Legal and Constitutional Affairs (2015) summarise indirectly provide the solution to the issues raised by Hall (2010) and Proulx et al (2006):

"AFAC considers that Residential Sprinklers should also be considered by the committee. Containing or suppressing fires, in residential properties substantially increases the amount of time occupants have to escape harm. If all new houses were to be provided with sprinklers, lives would be saved and injuries reduced…"

Source: pg. 6, AFAC (2015) Submission on Residential Fire Safety to Committee to Senate Standing Committee on Legal and Constitutional Affairs.

The writer is of the opinion that based on past submissions to the Australian Government that mandating the installation of sprinklers in houses is not seen as being cost effective when compared to falls where deaths due to accidental falls were 37 times[1] that due to fires. Smoke alarms are mandated for houses as they are more effective as shown in AFAC based research (2005). AFAC (2015) do make an extremely valid point for residential sprinklers but their submission fell short of making the sprinklers mandatory other than in some rest homes. As a result and also because of the requirements of some water supply authorities residential sprinklers are seen as being unaffordable. Even if sprinklers in houses were backed by the Government as providing a safe residence for vulnerable residents so that and suitable for "independent living", then they may prove to be cost effective in a more total picture[2] as newer forms of housing due to synthetic furnishings and the provision of open planning amongst other things result in a much shorter ASET[3]. Given the impact of ageing over the next few decades and trend of housing design and construction it can be argued that vulnerable residents have a right for optimum safety in their existing homes without being penalised cost wise for the installation of systems that will extend ASET so that firefighters can effect rescue beyond the 660 seconds calculated by Proulx et al (2006). This is what creates the conundrum.



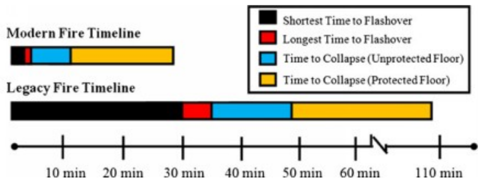




**Figure 1: Firefighter Arrival Time Matches RSET**

[1] Changes were made in NCC 2016 requiring slip resistant construction for access ramps and decks. Residential sprinklers as advocated by AFAC (2015) did not generate the same response due to the performance of smoke alarms across the entire population. Mandating change appears to be less suitable than targeted response as part of the whole solution. See footnote 2.

[2] See AHURI study by City Futures, Faculty of Built Environment, UNSW for general findings re the argument of
residents ageing in place as opposed to moving into retirement villages and other forms of aged care establishments.

[3] Kerber S,(2012), *Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes*, Underwriters Laboratories – overall intent of publication. See also Fraser-Mitchell J and Williams C,
(2009), *Open flat layouts; Assessing life safety in the event of fire*, NHBC Foundation re impact of open planning which would reduce ASET. Shown from the results of full scale room fire testing.

## 2.0 DEMONSTRATING THE CONUNDRUM

### 2.1 AGEING CONTINUES

Two comprehensive studies being Miller and Davey (2007) and Xiong, Bruck and Ball (2016), clearly indicate the risk of not surviving a fire as being related to age and the associated functional limitations **Table 2** below shows the fatality rate shows that age alone is the fourth main characteristic of victims. Other more relevant characteristics in order of importance are drug intake, discarded cigarettes, and living alone, all of which are relevant factors for the +65 year age group[4].

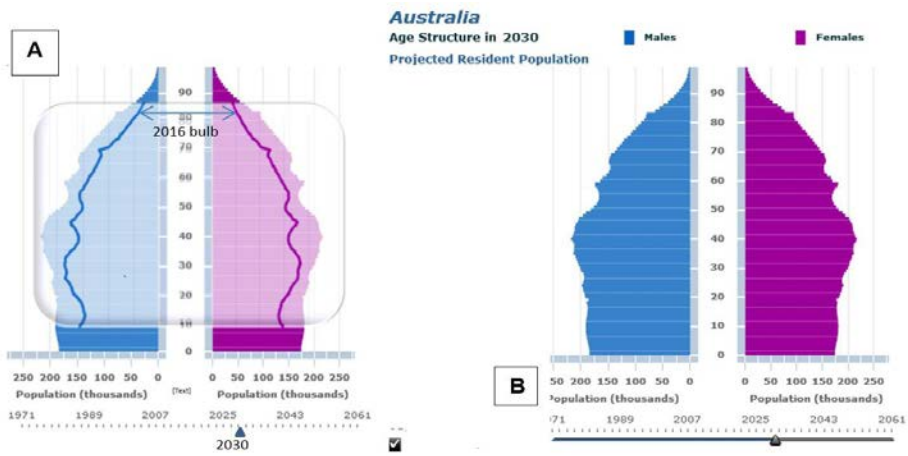
Unintentional Ibm House Fires Rates per 100,000 population

**Table 2: Number of Deaths / 100,000 Population – International Comparison.**

| Unintentional Injury From House Fires Rates per 100,000 population | | | | | |
|---|---|---|---|---|---|
| Age Group | R | | | | |
| | Australia | NZ | Japan | UK | US |
| 0 to 4 | 1.6 | - | 0.5 | 0.7 | - |
| 5 to 9 | 0.5 | - | 0.2 | 0.3 | 1 |
| 10 to 14 | - | - | 0.2 | 0.2 | 0.5 |
| 15 to 19 | 0.6 | - | 0.1 | 0.4 | 0.4 |
| 20 to 24 | 0.4 | - | 0.1 | 0.4 | 0.6 |
| 25 to 29 | - | - | 0.1 | 0.6 | 0.6 |
| 30 to 34 | 0.4 | - | 0.3 | 0.8 | 0.6 |
| 35 to 39 | 0.5 | - | 0.3 | 0.8 | 0.8 |
| 40 to 44 | 0.5 | - | 0.5 | 0.8 | 0.8 |
| 45 to 4 | 0.5 | - | 0.5 | 0.8 | 0.8 |

| | | | | | |
|---|---|---|---|---|---|
| 9 | | | | | |
| 50 to 54 | 0.8 | - | 0.7 | 0.8 | 1.1 |
| 55 to 59 | 0.7 | - | 0.7 | 0.8 | 1.1 |
| 60 to 64 | 1 | - | 1 | 0.9 | 1.1 |
| 65 to 69 | 1.1 | 0.6 | 1.2 | 1.22 | 1.7 |
| 70 to 74 | 1.6 | 0.6 | 1.5 | 1.22 | 1.7 |
| 75 to 79 | 2 | 1.8 | 3 | 1.22 | 2.4 |
| 80 to 84 | 3.3 | 1.8 | 5 | 3.2 | 2.4 |
| 85+ | 4.6 | 4.4 | 5.2 | 3.2 | 3.5 |

In the year 2031 the first “baby boomers” will have reached the grand age of 85 years young heralding an age of increased risk of unintentional injury/deaths from smoke and fire in housing. The rate for Australia, New Zealand and Japan is greater than 4 times the US averaged level of risk which agrees with the statements made by Miller and Davey (2007)[5]. The “baby-boomer” ageing “bulge” in the population age profile is shown for 2016 which is “projected” on to the 2030 profile in Figure 2 below;




[4] Xiong, Bruck and Ball (2016)

[5] Miller and Davey (2007) also confirm these statements by reference to international research from the UK, Japan, USA, as well as numerous Australasian Studies such as Rhodes and Reinhold (1998), Brennan and Thomas (2001), Duncanson et al

(2001-2002) and Zhang et al (2006). The Australasian research continued on with an extensive study by Barnett (2008) relating to fire risk and elder residents. This study was similar to Miller and Davey (2007) in some ways but far more extensive.

**Figure 2: (A) Baby Boomers: 70 in 2016 – start of the "bulge" (B) Baby boomer bulge in 2030.**

Given that ageing will continue to be an issue along with associated problems of caring for this age group inclusively the option of ageing in place needs to be considered which includes an appropriate level of fire protection which is commensurate with their evacuation capability [6] and the changing nature of the design, construction and furnishing of housing Kerber (2012) [3] in terms of the change in egress time available as shown in **Figure 1**. The change is reflected in the modern house where the minimum time for untenable conditions to be reached is some 120 seconds[3]. Kerber (2012) confirms this from the results of full scale room fire testing[3] . Kerber also notes the average Fire Brigade (Service) arrival time at 11 minutes or 660 seconds as shown in **Figure 1**. Fire fighters cannot be expected to rescue residents in dangerous conditions which occur some 540 seconds after flashover. Smoke detectors do help[7] but are only as good as the sound level and frequency of their "sounders"[8] in terms of causing residents to wake up from a deep sleep. Residents without a carer or appropriate household support member present at the time may not be able to escape. The firefighter then becomes the person who will affect the evacuation. AFAC[9] therefore also see the conundrum and raise the issue of the installation of sprinklers the success of which has been demonstrated in the USA. This is backed up for Australasia by Duncan and Wade (2001).

## 2.2 CURRENT STATUS FROM THE STATISTICS AND CAN THE RISK BE MITIGATED?

If sprinklers are to be ignored then the Fire Brigade will be responsible for bring the fire under control unless the scenario is that of a small fire which has burned itself out. The effectiveness of confining the fire to the room or object of fire origin deteriorated between 2000 and 2005 and most likely beyond.[10] Given that 47% of all building fires occurred in Class 1 buildings (houses) between 1974 and 2005 with the room of fire origin resulting injury varying as follows[11];

- 40.6% in kitchen which is even more prevalent now given that most new homes are now open plan
- 21.9% in the bedroom
- 11.5% in the lounge or 13.8% in lounge/dining areas

The burning characteristics of furnishings (upholstered chairs and mattresses) were tested over a period of some 30 years[12] and it was found that the modern materials comprised highly flammable material which decreases the time available for escape due to high temperatures, loss of visibility due to black and hot smoke and lethal gases occurring within a shorter space of time from the outbreak of a flaming or smouldering fire.

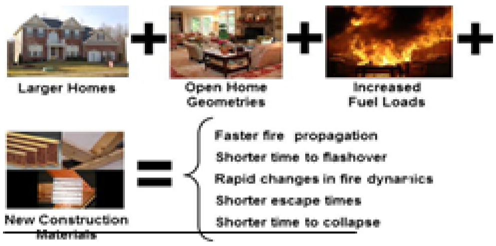



**Figure 3 The Changing Fire Scenario – Time Available for Escape – shorter escape time[13]**

[6] See Proulx et al (2006) for RSET taking into account the functional limitations associated with the +65 year age group.
[7] Bukowski RW, Peacock RD, Averill JD, Cleary TG, Bryner NP, Walton WD, Reneke PA, and Kuligowski ED, (2004),Performance of Home Smoke Alarms – Analysis of the Response of Several Available Technologies in Residential Settings
[8] Bruck D, and Thomas I, (2009), Towards a Better Smoke Alarm Signal – an Evidence Based Approach, in the Fire Safety Science Proceedings of the Ninth International Symposium pp.403-414. Also see Summary Bulletin on Smoke Alarms in HMInfo Pack available at; http://www.homemods.info/publications-by-hminfo/summary/summary-bulletin-fire-safety-smoke-alarms
[9] AFAC Submission No. 5 to the Senate Standing Committee on Legal and Constitutional Affairs – "Inquiry into use of smoke alarms to prevent smoke and fire related deaths", August 2015. AFAC (an organisation representing all Fire Brigades and Emergency Services Organisations throughout Australasia) based their view on research carried out by Fire and Rescue NSW in 2005 and full scale room fire testing by CSIRO in 1999.
[10] NSW Fire Brigades (2005) Statistical Information Services, Australian Incident Reporting System, AIRS data, March.
[11] Australian Fire and Emergency Service Authorities Council (2009) Accidental Fire Injuries in Residential Structures: Who's at Risk, AFAC, Section 9.
[12] Bukowski RW, Peacock RD, Averill JD, Cleary TG, Bryner NP, Walton WD, Reneke PA, and Kuligowski ED, (2004), Performance of Home Smoke Alarms – Analysis of the Response of Several Available Technologies in Residential Settings

In summary the NIST Study of the burning characteristics of furnishings over 30 years showed a "drastic" decrease in the time taken to reach untenable conditions[12]. The increased use of plastics, usually in foamed materials underpinned this decrease i.e. from an average of 970 seconds to 130 seconds in the early 2000's[12,14 and 15]. At the same time alternative non-robotic[7,16] egress studies have shown that the time required by a resident to safely evacuate a house could vary by an alarming 827% where the time required could be of the order of 11 minutes (660 seconds), which exceeds 130 seconds by approximately 500%. The AFAC observation is therefore valid supporting the need for a reliable ASET extension system (e.g. use of water spray to control the fire and mitigate the risk. The problem is twofold being cost interacting with over standardisation causing residential sprinklers not to be cost-effective.

## 2.3 OCCUPANT CAPABILITY IN RESPONSE AND THE ASSOCIATED TIME TO ESCAPE

A large proportion of the Australian Population suffer from Dementia is projected to increase from 257,000 in 2010 (1.2%) to 981,000 in 2050 (2.8%)[17]. This is seen as a minimum given that early onset dementia issues will increase as will those with additional cognitive issues[18]. This will decrease their evacuation capability in terms of escape time (see also number of activities in RSET in **Figure 5**). However the capability of the residents is only as good as the time the reliability of their smoke alarm. Thomas and Bruck in an evidence based study carried out for the Australian Building Codes Board in 2009[19] (see **Figure 4**) showed how the 520Hz square wave was the most effective sound signature. It aroused 95.5% of the population from their sleep. This rate of response can be further increased by the addition of a "pillow shaker"[19,20]. When this type of alarm is associated with a photo-optical smoke detector then there is a reliable optimum early detection and warning device[19,20] providing the earliest possible start to evacuation, hopefully in accordance with a practised plan such as that issued by Queensland Fire and Rescue[21].

[13] Kerber S, (2012), Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes, Underwriter's Laboratories, US.

[14] A review of room fire test videos on U-tube; UL Legacy Fire tests; ABC Catalyst available on www.abc.net.au/catalyst/stories/4046289

[15] According to Bukowski and Peacock (1995) "Time to flashover in the room of fire origin could be taken as the overall House ASET because of the increased risk to other rooms in the house".

[16] A review of room fire test videos on U-tube; UL Legacy Fire tests; ABC Catalyst available on www.abc.net.au/catalyst/stories/4046289 and according to Bukowski and Peacock (1995) "Time to flashover in the room of fire origin could be taken as the overall House ASET because of the increased risk to other rooms in the house".

[17] Cutler H, Chao D, McKibbin R, Cheung S, and Pezzullo L, (2010), *Caring places: planning for aged care and dementia 2010-2050*, Access Economics, Report for Alzheimers Australia.

[18] 22% of NSW Population with a general mental health condition in McCausland R, Baldry E, Johnson S, and Cohen A, (2013), *People with mental health disorders and cognitive impairment in the criminal justice system; Cost-benefit analysis of early support and diversion*; p3; report is based on a paper presented at the Australian Human Rights Commission and University of New South Wales roundtable Access to Justice in the Criminal Justice System for People with Disability, held at the University of New South Wales on 22 April 2013. See also AIHW, (2007), Dementia in Australia; National data analysis and development, Catalogue No. AGE 53.

[19] Bruck D, and Thomas I, (2009), Towards a Better Smoke Alarm Signal – an Evidence Based Approach, in the Fire Safety Science Proceedings of the Ninth International Symposium pp.403-414.

[20] See Summary Bulletin on Smoke Alarms in HMInfo Pack available at http://www.homemods.info/publications-by-hminfo/summary/summary-bulletin-fire-safety-smoke-alarms

[21] Suggested method to develop a plan available at; https://www.fire.qld.gov.au/communitysafety/home/escape-plan.asp

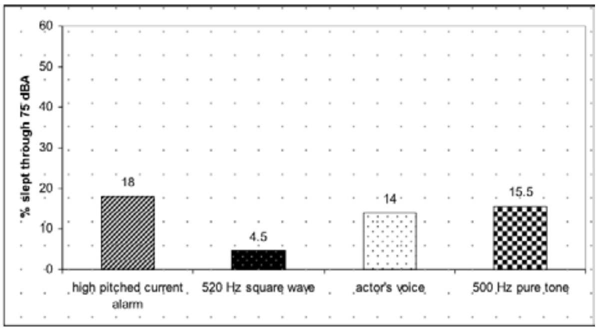



**Figure 4 – Comparison of Smoke Alarm Response – Source is as cited in Footnote[19].**

Proulx et al (2006) show the various steps in escape involving response and moving to a safe place. This is fully explained in Figure 5 below:


**Figure *5*: RSET Actions Proulx et al (2006)**

If the appropriate ASET was based on a RSET of 660 seconds allowing for a realistic margin of safety the expected protection system given[23] the burning characteristics and planning of the modern home would need to achieve untenable conditions for over 20 minutes. Duncan and Wade (2001)[23] demonstrate this in their study with a 98% success rate for residential sprinklers.

It should be noted at this stage that Fire Brigade (Service) advice re fire prevention, escape planning and the practice thereof is still extremely important and should not be ignored[24].Proulx et al's risk analysis of the Vulnerable Resident[6] shown in Figure 6 above supports the Escape Capability Analysis in **Figure 6** and the targeted use of Domestic Sprinklers[23] and the potential of the Water Mist System developed and tested by BRE Global[25]. This suggestion will be tested further in a subsequent section.

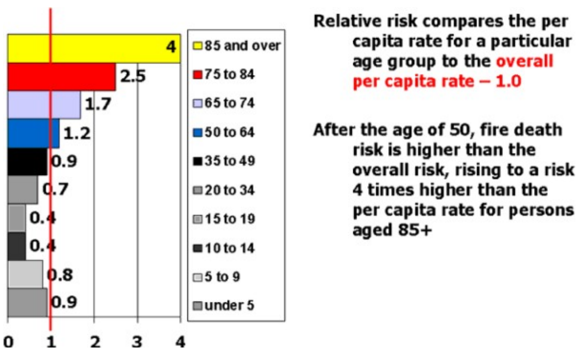



**Figure 6 – Risk Analysis of Resident Escape Capability according to Age.**
See also **Table 2** for the overall per capita rate of 1.0 from US Studies.

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[22] Babrauskas V, Fleming JM, and Russell BD, (2010), RSET / ASET a flawed concept for fire safety assessment, *Fire and Materials*, Vol. 34, pp. 341-355.
[23] Duncan C, and Wade C, (2001), Cost Effective Domestic Fire Sprinkler Systems, BRANZ, Paper presented at CIB World Congress, April, 2001, Wellington, NZ, pp. 39. ISSN: 0111-7505.
[24] See also findings from Miller and Davey (2007)
[25] BRE Global, (2015), *Personal Protection Systems (PPS), Guidance on the use, deployment and limitations of Personal Protection Watermist Systems in the homes of vulnerable people*, Issue No. 1, Joint Report BRE Global and London Fire Brigade.

## 2.4 FIRE BRIGADE RESPONSE AND THE RESPONSIBILITY OF RESCUE

Waters (1999)[26] shows that Fire Brigade or Fire Service Response has a community responsibility to save lives in event of a fire. Waters shows that it is unlikely that the response time of the first appliance will be within two minutes which is the time taken in numerous room fire tests for fire in a room to reach flashover where the conditions in the room will no longer support survival. The remainder of the house will be placed at risk especially with increased open planning so common in the modern house. If the response time is to be compared to the time taken for conditions in the room to reach 600$^0$C then a simple analysis of the time taken to complete the three main response activities is required;

- The time it takes for dispatching centre to receive the “000” call or in the case of automatic connection of a compliant smoke detector/alarm system a signal via a private monitoring station[27]; plus
- The time it takes for the first station to mobilise and the time it takes for the first appliance from this station to reach the house on fire; plus
- The time it takes to set up the fire ground, get water on to the fire and effect rescue.

Kerber (2012)[13] has shown that ASET can be as little as 120s and that according to Bukowski and Peacock (1995) “Time to flashover in the room of fire origin could be taken as the overall House ASET because of the increased risk to other rooms in the house”. According to an Australasian study on Fire Brigade response time will be more of the order of 10 minutes (PricewaterhouseCoopers, 2009). The time taken for the completion of Activity 1 in the case of a neighbour or resident ringing “000” may well be in excess of 2 minutes from ignition of the fire. In the case of detection by a compliant smoke alarm system the private monitoring company may quite well receive the notification in less than 1 minute but it may take another 1 minute to relay all the particulars to the Fire Brigade Despatch Office. The time taken for activity 2 may quite well be in excess of 2 minutes. When one considers the completion of activity 3 the overall time will most likely be well in excess of 4 times that taken to reach flashover. This may have been satisfactory for the 1970’s where the time to reach flashover was some 4 times longer but this is not the case any longer[12,13]. See **Figure 7** below for a typical timeline[13];

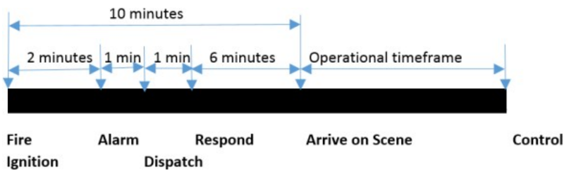


**Figure 7 – Fire Service Timeline Example (Kerber, 2012)[13]**

It is interesting to note that current Fire Brigade statistics do not appear to support this given the large percentage of house fires where the fire was confined to the room of fire origin. The time to flashover is so variable seeing it depends on the scenario present at the time. AFAC submission No. 5 (2009)[9] shows that smoke detectors/ alarms may not be the panacea for those residents with functional limitations impacting on their escape capability. Domestic Sprinkler systems provide one answer[23] in that they will control the fire and provide conditions suitable for firefighter initiated rescue.

# 3.0 SOLUTIONS AND CHALLENGES

The suggested solution needs to be sustainable. Many would see that any solutions that exceeded the provisions of the National Construction Code (NCC) 2016 for Class 1a and Class 1b buildings, which are the classifications appropriate for the Group Housing provided by Achieve Australia, would be unsustainable. Any solution therefore needs to be cost effective. Studies such as those carried out by

[26] Waters R, (1999), Fire Department Response Times vs. Flashover, Fire Engineering, Vol. 152, No. 2, accessed on 7/04/2016 at http://www.fireengineering.com/articles/volume-152/issue-2/features/fire-department.

[27] Depends on the resources of the Fire Brigade concerned as to whether or not a direct connection to their service can be accommodated.

BRANZ in 2001[19] confirm that the system is cost effective. This is, however, a NZ Study. This study was extended into Australia and the finding altered slightly due to additional factors such as Water Supply Authority requirements re water quality and other related factors. AFAC[9] recommended the solution developed in the BRANZ Study subject to the additional factors raised for targeted use with vulnerable or at risk communities such as would be the case with communities comprising Achieve Australia's Clients. The BRANZ Study concluded;

- It is feasible for a combined home plumbing and fire sprinkler system into a new three bedroom Australian home.
- The estimated cost per life saved for a combined sprinkler and plumbing system is sensitive to a number of factors. The Study suggested that such a system may be vital for targeted use with vulnerable at risk communities.
- A Code of Practice needs to be developed for its overall use.

Australian Standard AS 2118 Part 5: 2008[28] advocates a combined system which is seen as being cost effective. The requirements are still subject to the requirements of the Water Supply Authorities and the domestic water supply infrastructure especially in terms of water supply pressure in each residential area. It is interesting to note that Soja and Edwards in a Report on Water Quality and Domestic Sprinklers[29] found;

"*Microbial and chemical water potability tests were performed on a domestic fire sprinkler system over a period of 12 months. It was found that the microbial quality would not be hazardous to health where range pipe dead legs were up to 4.5m long for a water supply of equal or better quality used in this research. From this it is recommended that dead legs up to 3m could be used in Combination Domestic Fire Sprinkler Systems*[29]"

This finding could be discussed with the relevant Water Supply Authority and imposed as a design constraint on a system complying with either AS2118:5 – 2010 or NZS 4517: 2010[30] and a proposal put forward for the possible deletion of backflow prevention devices thus saving further costs[31]. There is still the issue of the adequacy of water supply pressures[31]. An alternative to using a towns- main supply is to have a separate storage tank on site with a small pump. The tank capacity is based on a duration of supply of 10 minutes minimum. Based on research into the reliability of sprinklers to control the fire being 95% a 10 minute capacity is in order. The above solution still involves the use of a fully compliant interconnected smoke alarm system.

Research carried out by BRE Global resulted in the development of their **Personal Protection System** (watermist)[32] for use in homes for vulnerable persons including group homes accommodating up to 6 persons (Class 1b under NCC 2016). A supplier with branches in Australia is Plumis. They market such a system and details may be found in their Handbook[33] which also complies with LPS 1655[32]. The heat/smoke detection system can also comply with the appropriate Australian Standard.

[28] Standards Australia, AS 2118 Part 5 (2008), *Domestic Fire Sprinkler Systems*, SAI Global.
[29] Soja E, and Edwards APR, (2006), *Domestic Fire Sprinkler Systems – Report on Water Quality, Reliability and Application to Other Property*, BRANZ Report No. FQ5011, New Zealand.
[30] Standards New Zealand (2010), NZS 4517:2010, *Fire sprinkler systems for houses*, Wellington, NZ.
[31] Note that the requirements may quite well vary from State to State and between Authorities because of local conditions and other factors. It is essential that the Authority is consulted prior to completion of design and that a competent person qualified under the FPAA Scheme is involved.
[32] LPS 1655 Personal Protection Water Mist Systems. A minimum installation would be the provision of heads to the Kitchen, Living/ Dining and Bedrooms (only those occupied by the Vulnerable Resident as a minimum). Also consult Automist Fixed Wall Head Handbook by Plumis Ltd (2015).
[33] Automist Fixed Wall Head Handbook V. 1.0.1 (2015), Plumis Ltd.

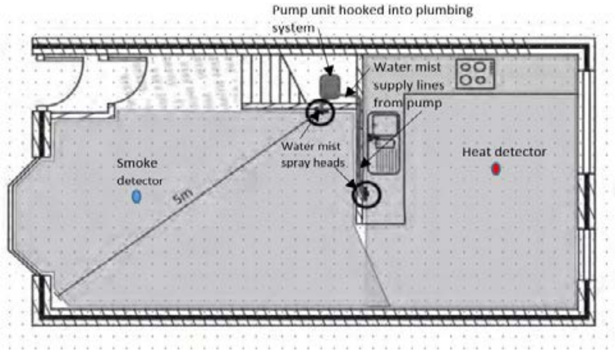


**Figure 8 – Layout of Watermist system to open plan Lounge/Dining/Kitchen – 2 fixed spray nozzles mounted at between 1400mm – 1500mm above floor level.**

**Table 3 – Results of Tests carried out by Exova Warrington on 1/7, 23/7 and 27/7 of 2015[34].**

| **Thermocouple location** | **Maximum temperature** | | | |
|---|---|---|---|---|
| | **Test 1** | **Test 2** | **Test 3** | **Test 4** |
| 75mm below ceiling | 799 | 365 | 172 | 164 |
| 1600mm above floor furthest from the fire | 233 | 128 | 51 | 100 |
| 1600mm above the floor closest to the fire | 227 | 58 | 39 | 42 |

Test 1 is a corner using free burn without any suppression. Tests 2 and 3 are centre room tests. Test 4 is a centre test but with ventilation. Tests 2-4 utilise water mist suppression to LPS 1655.

The Plumis Handbook[33] describes the operation of the system shown in Figure 8 and tested by Exova Warrington[34] with the results shown in Table 3 above as follows;

*"In the event of fire, the system is triggered automatically by the appropriate heat alarm[35] or a fire panel output. ….Unlike conventional sprinklers Automist can be stopped manually by pressing a button on its control panel or by cutting power…..As Automist uses much less water than a traditional sprinkler system…………Once triggered, a pump drives mains water through the unique nozzle unit, quickly filling the room with a dense fog. Water mist removes heat and displaces oxygen from the fire zone resulting in fire control…suppression. ……..increasing survivability. Adding water to a chip pan fire can greatly exacerbate the fire…..not true for water mist……The water mist technology has benefits for suppressing a greater range of fire scenarios, particularly fires that are shielded from the nozzle release point".*

The system performance has been proven by an extensive testing programme carried out by BRE as mirrored in BRE Global's Report[25]. The value of the PPS is that it can be used to provide a targeted form of protection. Consider the following example outlined in Figure 9.The targeted rooms are based on use and prevalent rooms of fire origin as outlined in AFAC commissioned report, "Who is at Risk?[36] " Most fires originate in the Kitchen followed by the bedrooms, and living/dining areas[36]. Assuming that the vulnerable resident was allocated bedroom 3 (see Figure 9) the PPS could be located in the kitchen, living/dining areas and bedroom 3. The remainder of the house still needs to be provided with a fully interconnected and monitored smoke alarm system (see also HM Info Summary Bulletin on Smoke Alarms[20]). This type of system will alert the carer, where the vulnerable resident requires assistance, regardless of the bedroom the carer occupies. It is assumed that the remainder of the residents will be able to evacuate in time i.e. those with the evacuation capability that matches the

[34] Exova Warrington Test Report, Ad-hoc test on water mist systems utilising the principles of the procedure defined in Draft BS8458: 2014: Annex B (ref. 356142).
[35] Recommended for kitchens. Optical smoke detectors elsewhere.
[36] AFAC, (2009), *Accidental Fire Injuries in Residential Structures: Who's at Risk?* Australasian Fire Emergency Service Council, July, 2009.

various fire scenarios. Alternatively a fully compliant domestic sprinkler system complying with AS2118.5 – 2008 could be installed where the level of reliability would be of the order of 95%[37].

## 4.0 CONCLUSIONS AND RECOMMENDATIONS

The current requirements of the National Construction Code 2016 for Class 1a (single houses) and 1b buildings (shared accommodation with a suggested cap of 6 persons)[38]. The needs of the residents should be inclusively considered and to this end the concerns of the Australian State Fire and Emergency Services[39] and the implications of the Research shown in this Paper where the time taken to reach non survivable fire conditions can be as little as two minutes need to be addressed. We may conclude that the installation of smoke alarms on their own may not provide the level of protection required to match the limited evacuation capability of the residents.

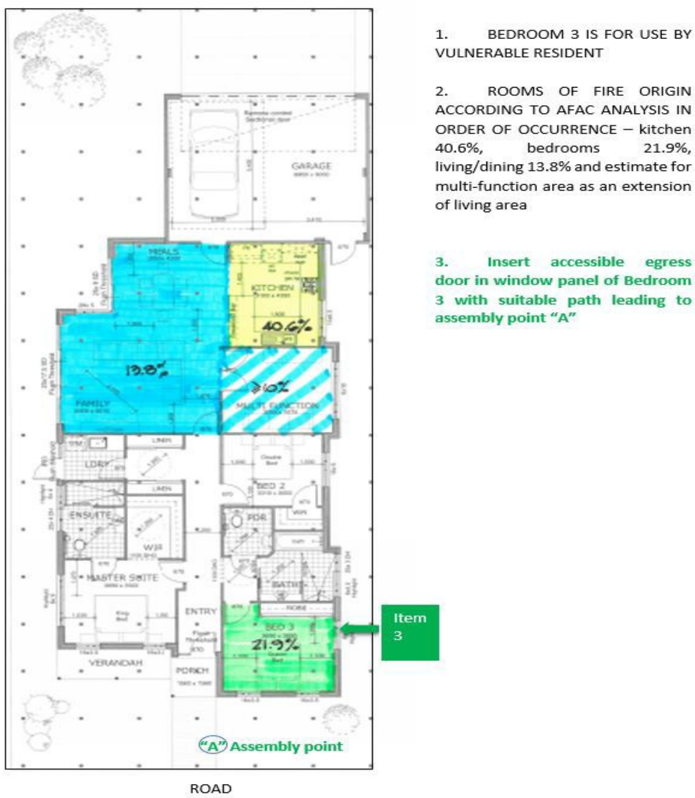


**Figure 9: Location of Watermist Protection Zones with entire house being provided with fully interconnected smoke alarm system.**

Source Concept Drawing of Liv

Benchmark costs[40] match the concerns of AFAC as reflected in their submission no. 5 to the Federal Government[9] regarding the installation of domestic fire sprinklers in accordance with AS 2118.5 – 2008. Research shows that similar installations are cost effective[23]. AFAC go on to recommend that the use of domestic sprinklers should be targeted in communities where the residents are vulnerable rather than mandating their use via the NCC.[36] BRE Global in the UK recommend a still more cost effective alternative in the form of water mist protection where water mist is directed on to the fire via

[37] Duncan C, and Wade C, (2001), Cost Effective Domestic Fire Sprinkler Systems, BRANZ, Paper presented at CIB World Congress, April, 2001, Wellington, NZ, pp. 39. ISSN: 0111-7505. Further study in 2002 by Soja E, showed that water quality in Domestic Sprinkler System did not pose health risk to water supplies so that Australian Water Supply Requirements that add cost to a basic system may need to be challenged.

[38] Group or shared accommodation is for a maximum of six persons.

[39] AFAC Submission No. 5 to the Senate Standing Committee on Legal and Constitutional Affairs – "Inquiry into use of smoke alarms to prevent smoke and fire related deaths", August 2015. AFAC (an organisation representing all Fire Brigades and Emergency Services Organisations throughout Australasia) based their view on research carried out by Fire and Rescue NSW in 2005 and full scale room fire testing by CSIRO in 1999

[40] Australian costs for residential sprinklers would be of the order of $4492 in 2013 if the economies of scale shown up in the Scottsdale experience (Newport Partners, 2013) were in place.

an adjacent smoke and/or heat detector. They have shown this system to be reliable through a series of fire tests. An example of their use is shown in Section 3.The recommendation therefore is for the use of full or targeted water mist systems (LPS 1655) in association with a fully compliant interconnected and monitored smoke alarm system[20, 19]. There is a need for additional research and the possible development of supplemental fire safety as part of a more comprehensive study of the safety aspects of ageing in place.

## REFERENCES


1. AFAC, (2015), *Inquiry into use of smoke alarms to prevent smoke and fire related deaths*, Submission No. 5 to the Senate Standing Committee on Legal and Constitutional Affairs, (AFAC an organisation representing all Fire Brigades and Emergency Services Organisations throughout Australasia based their view on research carried out by Fire and Rescue NSW in 2005 and full scale room fire testing by CSIRO in 1999).
2. AFAC, (2009), *Accidental Fire Injuries in Residential Structures: Who's at Risk?* Australasian Fire Emergency Service Council, July, 2009.
3. AIHW, (2007), *Dementia in Australia; National data analysis and development*, Catalogue No. AGE 53. Australian Bureau of Standards, (2006), Health of Older People in Australia: A snapshot, Publication 4833.0.55.001. , available at; **http://www.abs.gov.au/ausstats/abs@.nsf/mf/4833.0.55.001**
4. Australian Fire and Emergency Service Authorities Council (2009) *Accidental Fire Injuries in Residential Structures: Who's at Risk*, AFAC, Section 9.
5. Automist, (2015), Fixed Wall Head Handbook V. 1.0.1, Plumis Ltd. Babrauskas V, Fleming JM, and Russell BD, (2010), RSET / ASET a flawed concept for fire safety assessment, *Fire and Materials*, Vol. 34, pp. 341-355.
6. Barnett ML, (2008), Risk Factors and Incidence of Residential Fire Experiences Reported Retrospectively, *PhD Thesis*, Victoria University.
7. BRE Global, (2015), *Personal Protection Systems (PPS), Guidance on the use, deployment and limitations of Personal Protection Watermist Systems in the homes of vulnerable people*, Issue No. 1, Joint Report BRE Global and London Fire Brigade
8. Brennan P and Thomas I (2001) *Injuries and Fatalities in Fires: A Continuum*, in eds. Delichatsios M, Dlugogorski B, and Kennedy EM, Proceedings of the 5th AOSFST, Australia, pp. 351 – 365.
9. Bruck D, and Thomas I, (2009), *Towards a Better Smoke Alarm Signal – an Evidence Based Approach*, in the Fire Safety Science Proceedings of the Ninth International Symposium pp.403-414
10. Bukowski RW, Peacock RD, Averill JD, Cleary TG, Bryner NP, Walton WD, Reneke PA, and Kuligowski ED, (2004), *Performance of Home Smoke Alarms – Analysis of the Response of Several Available Technologies in Residential Settings*. National Institute of Standards and Technology, Gaithersburg, MA.
11. Bukowski RW, (1995), R. W., *Predicting the Fire Performance of Buildings: Establishing Appropriate Calculation Methods for Regulatory Applications*, Interscience Communications Limited. ASIAFLAM '95. International Conference on Fire Science and Engineering, 1st. Proceedings. March 15-16, 1995, Kowloon, Hong Kong, pp. 9-18,
12. Cutler H, Chao D, McKibbin R, Cheung S, and Pezzullo L, (2010), *Caring places: planning for aged care and dementia 2010-2050*, Access Economics, Report for Alzheimers Australia
13. Duncan C, and Wade C, (2001), Cost Effective Domestic Fire Sprinkler Systems, BRANZ, Paper presented at CIB World Congress, April, 2001, Wellington, NZ, pp. 39. ISSN: 0111-7505.
14. Duncanson M, Woodward A, and Reid P, (2002), Socioeconomic Deprivation and Fatal Unintentional Domestic Fire Incidents in New Zealand, 1993- 1998, *Fire Safety Journal*, Vol. 37, pp.167-179.
15. Exova Warrington Test Report (2014), *Ad-hoc test on water mist systems,* utilising the principles of the procedure defined in Draft BS8458: 2014: Annex B (ref. 356142).
16. Fraser-Mitchell J and Williams C, (2009), *Open flat layouts; Assessing life safety in the event of fire*, NHBC Foundation.
17. Judd B, Liu E, Easthorpe H, Davy L, and Bridge C, (2014), *Downsizing amongst older Australians*, Australian Housing and Urban Research Institute, University of New South Wales, AHURI Report No. 214, ISSN: 1834-7223 and ISBN: 978-1-922075-42-0.
18. Kerber S, (2012), *Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes*, Underwriters Laboratories
19. LPS 1655 Personal Protection Water Mist Systems (2015). *A minimum installation would be the provision of heads to the Kitchen, Living/ Dining and Bedrooms* (only those occupied by the Vulnerable Resident as a minimum). Also consult Automist Fixed Wall Head Handbook by Plumis Ltd (2015).
20. McCausland R, Baldry E, Johnson S, and Cohen A, (2013), *People with mental health disorders and cognitive impairment in the criminal justice system; Cost-benefit analysis of early support and diversion*; p3; report is based on a paper presented at the Australian Human Rights Commission and University of New South Wales roundtable Access to Justice in the Criminal Justice System for People with Disability, held at the University of New South Wales on 22 April 2013
21. Miller I, and Davey J, (2007), *The Risks Perceptions and Experiences of Fire Among Older People*, Report for NZ Institute for Research on Ageing, Heimdall Consulting Ltd.
22. Newport Partners, (2013), *Home Sprinkler Cost Assessment – 2013*, The Fire Protection Research Foundation, NFPA

23. NSW Fire Brigades (2005), *Data*, Statistical Information Services, Australian Incident Reporting System, AIRS data, March 2005.
24. PricewaterhouseCoopers (2009), *Describing the Value of the Contribution from the Volunteer Fire Brigade*, Fire Research Report No. 100, NZ Fire Service Commission
25. Riskcomm.com, (2016), *The odds of serious risks that people can relate to*, available at; http://www.riskcomm.com/visualaids/riskscale,datasources.php (where direct reference source for risk scores are derived is http://www.nsc.org/lrs/statinfo/odds.htm - all records are from 2002)
26. Siarnicki RJ, (2001), *Residential Sprinklers: One community's experience twelve years after mandatory implementation*, Applied Research Project, Executive Fire Officer Program, National Fire Academy.
27. Soja E, and Edwards APR, (2006), *Domestic Fire Sprinkler Systems – Report on Water Quality, Reliability and Application to Other Property*, BRANZ Report No. FQ5011, New Zealand
28. Standards Australia, AS 2118 Part 5 (2008), *Domestic Fire Sprinkler Systems*, SAI Global. Standards New Zealand (2010), NZS 4517:2010, *Fire sprinkler systems for houses*, Wellington, NZ.
29. *UL Legacy Fire tests*; ABC Catalyst available on; www.abc.net.au/catalyst/stories/4046289
30. Waters R, (1999), Fire Department Response Times vs. Flashover, Fire Engineering, Vol. 152, No. 2, accessed on 7/04/2016 at http://www.fireengineering.com/articles/volume-152/issue-2/features/fire-department
31. Xiong L, Bruck D and Ball M, (2016), Preventing accidental residential fires; the role of human involvement in non-injury house fires, *Fire and Materials*, published in Wiley Online Library DOI: 10.1002/fam2356.

**COMMENTS**

**TO**

**AUSTRALIAN BUILDING CODES BOARD**

**April 2018**

# Response 2
# NCC 2019
# DV2 and DV3
# Access and Ramp Verification Methods

PROVIDED BY:

**ENABLING BUILT ENVIRONMENT PROGRAM**

**Faculty of Built Environment**

**UNSW – Sydney**

# 1. Summary

The ATM for DV2 was issued well after the ATM for DV3 Ramps and has altered the entire approach where EBEP in consultation with the DV2 Team now see the design of ramps as part of the accessway system in each building (see Figure 1 below) , even to the point where they may be integrated with a level walking path, passage or corridor. The verification method represented in the flow chart - Figure 2.1 of the Ramps Verification Document is considered unsuitable as it relates only to ascent whereas it is essential to check for descent given the increased risk of tipping and “skidding” with increasing gradients. The Verification Method Flow Chart shown in the original EBEP Submission includes a detailed check for descent and should be adopted.

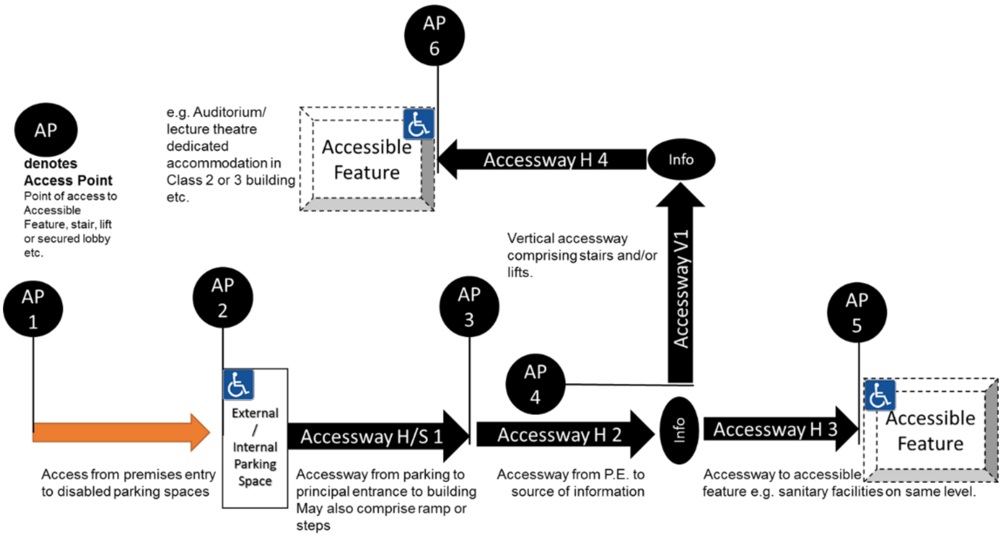


*Figure 1: Reference Model/ Framework for Access*

The Verification Matrix shown in Appendix C of the DV2 Handbook shows that it would be a vast improvement if the Ramps VM became a subset of DV2. Stairs should be considered in the same context. The persona derived for the testing of all accessible areas would then be derived using a common Occupant Characterisation method.

It is for this reason that the EBEP Response for DV2 has been combined with Ramps. The DV2 team have also challenged the Ramps Verification Method as being too narrow, specific and incomplete (no descent) as noted above. This challenge is to be included for reassessing the appropriateness of the assessment method.

# 2. Structure of Response

This response addresses the proposed Verification Methods for Access and Ramps, DV2 and DV3 respectively.

## Part One – Ramps Verification Method

- The Challenge – Sections 1.1 – 1.2 including
  - A possible way forward considering all ramp users[1]
- Response to the challenge Section 2 including
  - The misfit of Cappozzo (1991) – adopted for methodology only
  - The A-90 conundrum and persona

## Part Two – DV2 Access Verification Method

- Suitability of Direction
- Verification Method wording
- The Equity Question
- Integration with FSVM

[1] Sanford JA, Story MF, and Jones MJ, (1997) An analysis of the effects of ramp slope on people with mobility impairments, Assistive Technology, Vol.9, No.1 pp. 22-33, DOI: 10.1080/10400435.1997.10132293

# PART ONE

# RAMPS VERIFICATION METHOD

EBEP SUBMISSION

# 1. The Challenge

## 1.1 Cappozzo and Canale's work is totally inappropriate for NCC DV3

The argument is;

1. Cappozzo's research subjects were 5 well trained and fit male paraplegic athletes aged 30-41 and while the assessment method may be correct it is unworkable and not representative of our target group of A90 wheelchair users of all ages and abilities.
2. Canale's work research is an extension of Cappozzo and not helpful
3. (a) and (b) are a complete mismatch with the A90 profile used in the NCC/AS1428 and cannot be replicated for expected building occupants of public buildings.
4. The work is about ascending ramps and not descents as well which are more hazardous
5. As the NCC covers all buildings from child care centres to aged care facilities we should be thinking outside the parameters of AS1428.1 which is 18-60 years of age and recommending 1:20 maximum gradient for certain buildings on safety grounds – even for a minimal 190mm rise or similar.
6. The work of Sanford et al (1997)[1] is more suitable due the sample size and composition.

## 1.2 A possible way forward considering all ramp users

### 1.2.1 Maximum Gradient

Section 1.1 (6) stated that the work of Sanford et al (1997)[1] is more suitable than that of Cappozzo. In this research Sanford and his team conducted a study to;

*"……………. evaluate the usability of the range of ramp slopes allowed under the current ADA accessibility guidelines. One hundred seventy-one subjects of all ages and using different types of mobility aids traversed a 30-foot ramp varying in slope from 1:8 to 1:20. Data were recorded for pulse rate, energy expenditure, rate of travel, distance traveled, and the location of rest stops. Findings show that among all subjects only a few manual wheelchair users had difficulty traversing all 30 feet in ascent, even on slopes as steep as 1:8. Based on these results, changes to the technical requirements for ramp slope and length cannot be recommended at this time"*

We would agree from the Desk Audit carried out as Stage 1 of the Ramps that there is lack of agreement amongst researchers about ramp gradients and their impact on pedestrians with various forms of mobility impairment. Recommendations vary widely.

We would agree that the sample chosen for the study reflected the population profile at the time but there is a changing trend as shown in the ABS Data to the year 2030 and beyond in terms of ages > 65 years and morbid obesity as a comorbidity of ageing. This is not reflected in the composition of the sample described in ***Table 1*** below;

*Table 1: Sanford et al (1997) – Sample reflecting population profile*

| Age ears) | Crutches or cane | | Walker | | Manual wheelchair | | Electric wheel-chair | | Scooter | | Artificial leg or foot | | Leg or foot braces | | No aid/ activity limitation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | M | F | M | F | M | F | M | F | M | F | M | F | M | F | M | |
| Under 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 2 |
| 6-16 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 5 |
| 17-34 | 2 | 2 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 1 | 0 | 15 |
| 35-54 | 7 | 8 | 2 | 1 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 1 | 2 | 3 | 1 | 1 | 31 |
| 55-74 | 20 | 19 | 7 | 3 | 5 | 4 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 69 |
| Over 75 | 25 | 14 | 15 | 4 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 70 |
| Total | 54 | 44 | 25 | 8 | 16 | 10 | 1 | 1 | 0 | 1 | 1 | 3 | 10 | 11 | 5 | 2 | 192 |

The sample above does however reflect our mobility model as presented in Figure 3.14 of the DV2 Submission in terms of the assistive aids;

- Crutches
- Cane
- Walking frame
- Manual wheelchair
- Power wheelchair
- Mobility Scooter
- Artificial leg, foot, and braces
- No mobility impairment or activity limitation

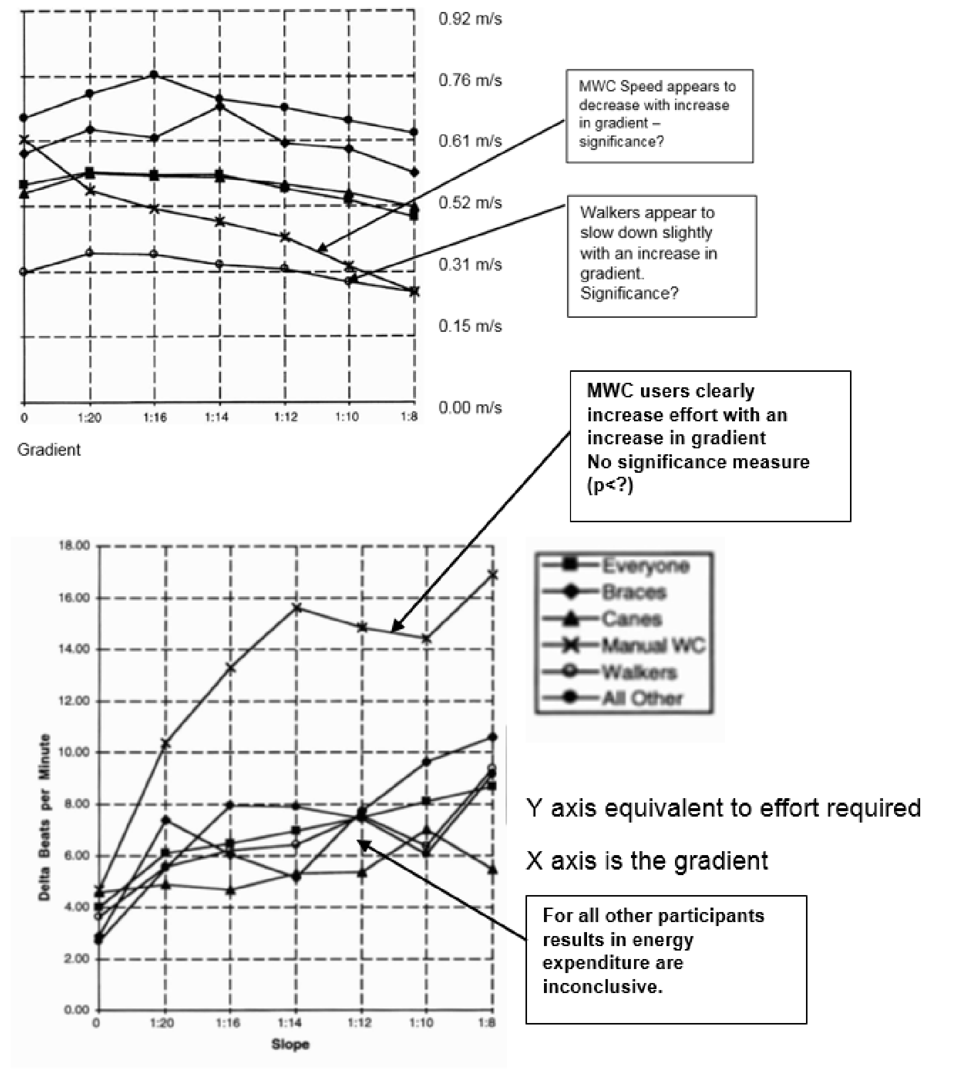


*Figure 2: Sanford et al (1997) (a) Movement speed and gradient (b) Energy expenditure and gradient – pulse rate*

No significant relationships appear in **Figure 2** above except that that MWC users' energy expenditure increased with gradient. What increases the value of this study is the user assessment of the gradients. The rating scale used unfortunately is not the Borg Scale so that the ratings cannot be triangulated with the energy expenditure measurements shown in Figure 2(b) above. What we can conclude to a reasonable degree is that ramps with a gradient exceeding 1:8 will require a disproportionate amount of effort which users rated above 6/10 in terms of difficulty. 1:8 is also seen as an upper limit for walkers in terms of falling. This is especially the case where the surface is contaminated by oil or is merely wet. This is supported by Chiou et al (2003) and Cham and Redfern (2000). Many other researchers support the use of shorter steeper ramps than longer ramps with a lesser gradient. The user survey in the Stage 1 Ramp Study found a general dislike for short steep ramps but the details show that this related to a gradient on 1:6.

**THE MAXIMUM GRADIENT TO BE CONSIDERED IN THE PBD IS 1:8 OR $7^0$**
**As suggested in the executive summary of the EBEP Submission**

This addresses the entire mobility model in Figure 3.14 of the DV3 Submission but not carried through into the Handbook

### 1.2.2 Crossfall

Based on the work of Holloway and Tyler (2013)[2] the crossfall specification needs to consider that the occupant is over the age of 65 years, is morbidly obese (BMI>35 and Waist Girth > 1200mm) and has reduced strength due to sarcopenia

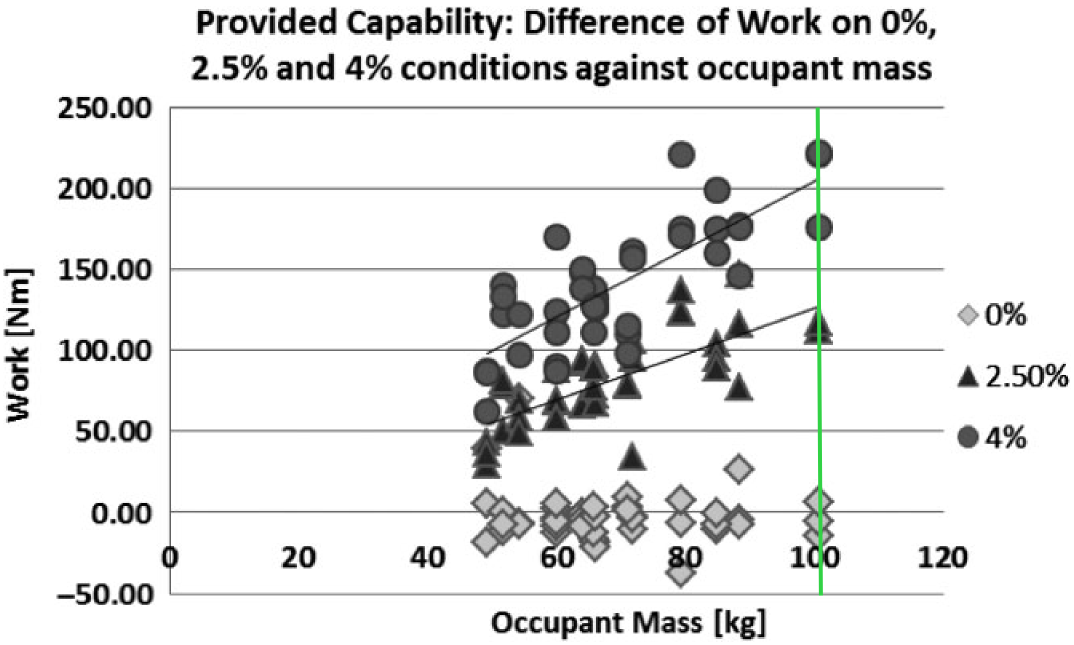


*Figure 3: Crossfalls vs. Occupant Mass and Gradient (Holloway and Tyler, 2013)[2]*

The recommended crossfalls are based on minimising the amount of additional work with increased gradients that reflects the data in Figure 2(b)

**1:14 – 2.5% which is 1:40**
**1:12 – 2.0% which is 1:50**
**1:10 – 1.0% which is 1:100 as additional work will most likely not exceed 25Nm**
**1:8 - 1.0% which is 1:100 as additional work will most likely not exceed 25Nm**
**THIS REFLECTS A MASS OF 100KG+ as indicated via the Green Line in Figure**

### 1.2.3 Surface Profile

Appendix B, Table 5.1 includes surface characteristics where the major concern from the literature[3] and values were included in the appendices of the original verification paper[4]. As explained in the latter there is no clear-cut association between slip resistance and rolling resistance and yet there are instances where marked surface roughness (mean profile depth of 2mm plus) can in fact increase the rolling resistance to a point where long run ramps of 1:20 can become a problem for MWC users. This is caused by the additional energy expenditure required to cope with manoeuvring. Uneven surfaces can also cause problems for walkers including those with crutches, walking frames and canes;

[2] Holloway C and Tyler N (2013) A micro-level approach to measuring the accessibility of footways for wheelchair users using the Capability Model, *Transportation Planning and Technology* Vol. 36, No. 7, pp. 636-649.
[3] Sauret et al (2012) Assessment of field rolling resistance of manual wheel chairs. *JRRD* Vol.49, No.1, pp.63-74.
[4] EBEP Stage 2 Submission on Ramps.

- Walkers who are morbidly obese have a distinct problem with balance and often walk with a disturbed gait – uneven surfaces can promote tripping[5] associated with toe clearance.
- Older walkers with a shortened stride when tired develop a fatigued gait with an extremely low toe clearance.
- Walking frames and crutches where uneven surfaces can obstruct the even and balance placement of walker frame "feet" and or small diameter caster wheels.

When this coupled with the concern for loss of traction for MWC's and the increase of the required coefficient for shoes and ramp surfaces especially for gradients in the region of 10 degrees [6] then the surface profile should be controlled as suggested below given that a 1 mm variance can promote tripping[5]. We suggest the following;

| |
|---|
| **1:14 – 0-2mm**<br>**1:12 – 0-2mm**<br>**1:10 – 0-1mm**<br>**1:8 - 0-0.5mm** |

### 1.2.4 Slip Resistance

Slip resistance is extremely important for all ramp users as it can reduce the risk of loss of traction for MWC and PWC at low speeds[7]. It also reduces the risk of slipping and is critical at the steeper gradients. Based on the work of Chiou et al (2003), Cham / Redfern (2000) and the IDGO team at the University of Salford we recommend the following;

| | |
|---|---|
| **1:14 – P4/R11**<br>**1:12 – P5/R12**<br>**1:10 – P5/R12**<br>**1:8 - P5/R12** | **It is imperative that the surface concerned is also assessed for impact on rolling resistance such as deep pile carpet** |

### 1.2.5 Length of Run

EBEP in reviewing DV3 in association with DV2 and occupant capability propose a need to correct an interpretation of the total effort associated with MWC users negotiating ramps. If we consider the following based on a complimentary study[8] to that of Sanford et al (1997)[1]. This recommendation was included as the "Graphical Method" in Appendix C in Figure 5.7.

[5] Loo-Morrey et al (2003) *Trip Feasibility Study*, Health and Safety Laboratories UK, Report HSL/2006/77

[6] Cham R and Redfern MS, (2000), *Slip potential during load-carrying* in Proceedings of the International Society of Biomechanics Annual Meeting.

[7] Is also a function of tyre pressure as highlighted in the Appendices to the Verification Method in the EBEP Submission.

[8] Kim et al (2014) Effects of ramp slope, ramp height and users' pushing force on performance, muscular activity and subjective ratings during wheelchair driving on a ramp International *Journal of Industrial Ergonomics*, Vol. 44, pp. 636-646. User ratings were used to triangulate the energy expenditure measures with the user estimations developed during the study on the Borg scale and the relationship was found to be statistically significant as shown in **Table 2** ($p<.01$)

*Table 2: Kim et al (2014) Statistically significant relationships between not clear in Sanford et al (1997)*

| Dependent variables | | | P-value | | |
|---|---|---|---|---|---|
| | | | Slope | Height | Interaction |
| Performance | Total time | | **<0.0001** | **<0.0001** | **0.0006** |
| | Velocity | | **<0.0001** | 0.1866 | **0.0043** |
| Physiological characteristic | EMG activity | Extensor carpi radialis | **<0.0001** | **0.0134** | 0.1558 |
| | | Triceps brachii | **<0.0001** | **<0.0001** | **<0.0001** |
| | | Anterior deltoid | 0.2658 | **<0.0001** | **0.0003** |
| | | Posterior deltoid | 0.8763 | **<0.0001** | 0.5272 |
| | Pulse rate change | | **<0.0001** | **<0.0001** | 0.0984 |
| Perceived discomfort | While ascending | | **<0.0001** | **<0.0001** | **0.0118** |
| | While descending | | **<0.0001** | **<0.0001** | **0.0002** |

Referring back to Figures 2(a) and (b) from the Sanford Study[1] where the sample sizes for MWC were similar but the participants were older and comparing their subjective findings[1] with those in **Table 2** above we can develop a recommendation shown in **Table 3** that compliments those shown in Figure 5.7 of Appendix C:

*Table 3: Suggested Run lengths to be substituted in C6 – Graphical Method*

| Gradient | Run Length (18-64yrs) | Run Length (+65yrs and children) |
|---|---|---|
| 1:14 | 9.000 | 6.000 (decrease pushing force to 40N as per Kim et al, 2014) |
| 1:12 | 6.000 | 4.000 As above |
| 1:10 | 3.000 | 1.500 As above |
| 1:8 | 1.800 | 1.200 As above |

The outcomes from sections 1.2.1 to 1.2.5 have all been substantiated by the research albeit that the findings of Sanford et al (1997) were somewhat subjective. A matrix is therefore proposed in the next section as a default DV3 outcome and is more appropriate for use with DV2.

### 1.2.6 DV3 Default Matrix – suitable for all Ramp Users

The EBEP team now propose a default DV3 Matrix for use with the DV2 system. The table comprises two sets of users being the population between the ages of 18-64 years and the other being older persons and children. The tables are suitable for the mobility status defined in Figure 3.14 of the DV2 Verification Method. See Tables 4 and 5 below;

*Table 4: Default DV3 Matrix for use with DV2 – checked using pushing force of 60N.*

| Gradient | Ramp Run Length | Crossfall | Slip resistance | | Ramp surface evenness* |
|---|---|---|---|---|---|
| | | | Dry | Wet | |
| **1:8** | **1520** | 1:100 | P5 / R12 | **P5 / R12** | 0-.05mm |
| 1:9 | 1650 | 1:100 | P5 / R12 | **P5 / R12** | 0-.05mm |
| **1:10** | **1900** | 1:100 | P5 / R12 | **P5 / R12** | 0-1mm |
| 1:11 | 4500 | 1:75 | P5 / R12 | **P5 / R12** | 0-1mm |
| 1:12 | 6000 | 1:50 | **P4 / R11** | **P5 / R12** | **0-2mm** |
| 1:13 | 7500 | 1:40 | **P4 / R11** | **P5 / R12** | **0-2mm** |
| **1:14** | **9000** | **1:40** | **P3 / R10** | **P4 / R11** | **0-2mm** |

*Table 5: Default DV3 Matrix for use with DV2 – corresponds to a reduced pushing force of 40N*

| Gradient | Ramp Run Length | Crossfall | Slip resistance | | Ramp surface evenness* |
|---|---|---|---|---|---|
| | | | Dry | Wet | |
| 1:8 | 1200 | 1:100 | P5 / R12 | **P5 / R12** | 0-.05mm |
| 1:9 | 1350 | 1:100 | P5 / R12 | **P5 / R12** | 0-.05mm |
| 1:10 | 1500 | 1:100 | P5 / R12 | **P5 / R12** | 0-1mm |
| 1:11 | 2000 | 1:75 | P5 / R12 | **P5 / R12** | 0-1mm |
| 1:12 | 4000 | 1:75 | **P4 / R11** | **P5 / R12** | **0-2mm** |
| 1:13 | 5000 | 1:75 | **P4 / R11** | **P5 / R12** | **0-2mm** |
| 1:14 | 6000 | 1:75 | **P3 / R10** | **P4 / R11** | **0-2mm** |
| 1:15 | 7500 | 1:50 | **P2 / R9** | **P3 / R10** | **0-2mm** |
| 1:16 | 9000 | 1:50 | **P2 / R9** | **P3 / R10** | **0-2mm** |
| 1:17 | 10500 | 1:50 | **P2 / R9** | **P3 / R10** | **0-2mm** |
| 1:18 | 12000 | 1:50 | **P2 / R9** | **P3 / R10** | **0-2mm** |
| 1:19 | 13500 | 1:50 | **P2 / R9** | **P3 / R10** | **0-2mm** |
| **1:20** | **15000** | 1:50 | **P2 / R9** | **P3 / R10** | **0-2mm** |

***NOTES TO BE READ IN ASSOCIATION WITH TABLES 4 AND 5**

a) The shaded column addresses several factors including vibration rates, rolling resistance, and other considerations that impact on energy expenditure or perceived comfort. See Appendix for details.

b) Any surface on a ramp with a gradient > 1:14 should not be carpeted and is not included in these tables. The reason is that rolling resistance figures for long pile carpet or carpet with substantial thickness of underlay are not available.

c) Every ramp system should be re-assessed using the EBEP Verification flow chart to check the impact of surface characteristics mentioned in (b).

d) Ramp systems must be assessed comprising more than two interconnected graded runs also need to be verified by detailed assessment as in (c).

# 2. Response to the Challenge

## 2.1 Summary of DV3 changes to align with DV2

The Challenge has been addressed in section 1.2. The objectives of the original ATM for DV3 focussed on the wheelchair and mobility scooter. It did NOT include the full population profile for the ICF classification of Mobility Capability. Because of this EBEP recommends that:

1. **The Verification Procedure Flow Chart be revised to require that all PB designs comply with the default DV3 Matrix as shown in Table 4 and Table 5 of this submission and that any departure from this must be verified utilising the original DV3 Flow Chart outlined in the EBEP Stage 2 Ramp Submission using a pushing force of 40N[9].**
2. **All abutment heights must be verified via a stability check corresponding with that shown in Section 3.5.3 of the ABCB Draft DV3.**
3. **All references accepting 1:6 as the maximum gradient must be changed to 1:8 as the research does not support 1:6 when viewed across the entire population and the descent risk for MWC users. This is supported by Appendix B.1 of the ABCB Draft DV3**
4. **The ABCB DV3 Handbook has lost the rigour of the original EBEP Submission in the alteration of the Verification Flow Chart to that shown in Figure 2.1 of the ABCB Handbook. This has focussed too much attention on to the Cappozzo Study[10] which is unsuitable in terms of sample size and occupant characterisation. We suggest that the original EBEP verification flow chart be used as a subprocess of DV2.**
5. **We suggest that the DV3 Handbook be fully integrated into the DV2 Handbook and that this is completed as part of Stage 2 of DV2.**
6. **The MVC has been replaced with a stated pushing force that must not exceed 50% of the Maximal Voluntary Contribution as determined via EMG testing. This is substantiated by the research[8]. This is reflected in the maximum gradient of 1:8.**
7. **The DV3 Verification process be modified to cater for DV2.**
8. **All manoeuvrability checking utilises the A-90 Model Footprint and that Design Personas be developed using the Occupant Characterisation process to be developed in DV2**

## 2.2 The unsuitability of the Cappozzo and Canale Studies

The alteration of the DV3 Verification Model focussed attention on the composition of these Studies. The work of Sanford et al (1997) was included in the Desk Audit and integrated into the redefinition of the DV3 Model which ONLY utilises Cappozzo's Mechanical Model. Sanford et al (1997) drew many subjective conclusions from non-significant statistical relationships ($p>.05$). We agree that the Cappozzo Study related to fit paraplegic athletes, but the main value of the study was the metrics that underpinned the analysis. We also agree with the link to Canale but the important link that is absent from the Challenge in 1.1 is the link to a statistically significant study by Kim et al (2014) that replicated Sanford et al (1997). This study replaced a participation observation process that could NOT be used to triangulate the quantitative data with one that could be based on the Borg Scale[8]. It should

[9] AS/NZS 3695.2 and/or ISO 7176 re pushing force testing.

[10] Cappozzo et al (1991) replaced by altered design parameters located in Appendices A-G. Only the mechanical model is adopted as shown in Figure 3.2 of the ABCB DV3.

be noted that Sanford et al (1997) did note the value of the 1991 studies (Canale et al and Cappozzo et al) in terms of controlling the length of runs with gradients greater than 1:10.

## 2.3 Mismatch between the proposed DV3 Method and the A-90 Wheelchair.

The wording of section 3.6 of the ABCB DV3 handbook when matched against the information shown elsewhere other than the Appendices A-G appears to ignore the use of the A-90 footprint. The A-90 MWC is shown in Figure 5.1(a) of the DV3 Handbook. This wheelchair comprises a theoretical model where there are many properties and information that are missing so that the necessary safety test data (ISO 7176) was unavailable. To overcome this problem a candidate MWC was selected that most closely resembled the A-90 Model and the design persona based on the extensive list of research papers nominated in C.1 of Appendix C. **The characteristics are rigorously analysed in Table 5.2 of Section C.2 of Appendix C.** Also note that the candidate wheelchair has a user capacity of 160Kg which translates into a BMI of 40 (morbidly obese). The age of the occupant is over 65 years and the allocated pushing force is 40N (weak in terms of strength and adopts the physical comorbidity of sarcopenia). These characteristics compliment the work of Steinfeld et al (2010)[11].

**We recommend that all manoeuvrability checking utilise the A-90 Model Footprint and that Design Personas be developed using the Occupant Characterisation process to be developed in DV2.**

## 2.4 Remaining Aspects of the "Challenge"

The remaining issues of 1.1 are:

1. The work is about ascending ramps and not descents as well which are more hazardous
2. As the NCC covers all buildings from child care centres to aged care facilities we should be thinking outside the parameters of AS1428.1 which is 18-60 years of age and recommending 1:20 maximum gradient for certain buildings on safety grounds – even for a minimal 190mm rise or similar.
3. The work of Sanford et al (1997)[1] is more suitable due the sample size and composition.

[11] Steinfeld et al (2010) Anthropometry of wheeled mobility project, US Access Board, University at Buffalo, The State University of New York; Paquet and Feathers (2004) An anthropometric study of manual and powered wheelchair users; and other DHM research papers nominated in DV3 and DV2 EBEP Desk Audits

## Ascent and Descent

The DV3 process Chart in Figure 2.1 of the ABCB DV3 Handbook is taken directly from the Cappozzo Study and does not include descent. The Process Chart from the original EBEP submission is shown in Figure 4 below. It includes descent and needs to be incorporated with that shown in Figure 3.1 from the ABCB DV3 Handbook. The Figure 4 Process Chart needs to be incorporated with the DV2. See **Table 2** above re the associated risk as determined by Kim et al (2014) as a statistically significant relationship.

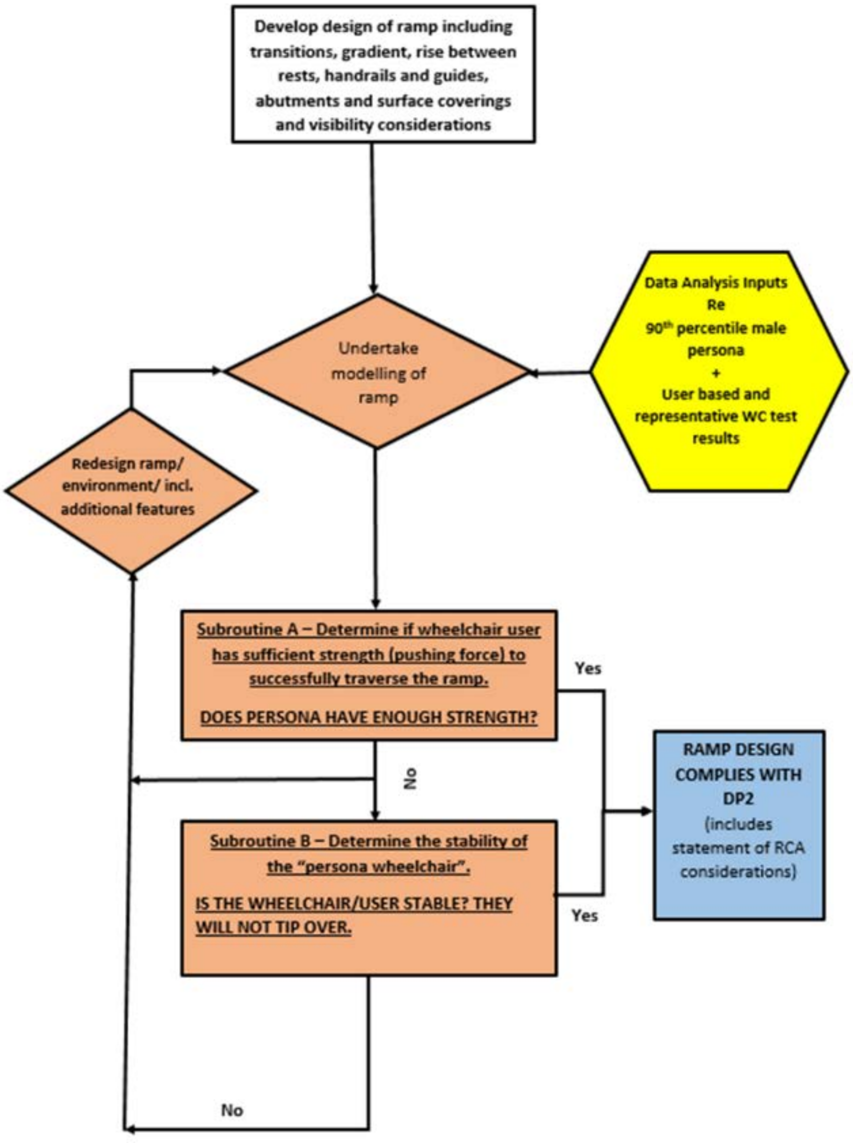


*Figure 4: Original DV3 Process Chart used with Verification Process Paper (EBEP)*

## Special Populations

The one major contribution from the discussion in section 1.2 was the need to revisit the impact of age on mobility. A review of the pushing force classification called up in the study by Kim et al (2014) of 60N is above that specified in ISO7176 which is 40N. This pushing force as shown in the original submission needs to be included in the engineering check for the current Design Persona who is also morbidly obese. The result of the further analysis of Kim et al (2014) results in the Default Matrix in ***Table 5***. The considerations in Section 1.2

has allowed an overview of the NCC Parameters e.g. the reduced run length for the 1:8 gradient.

### Suitability of the 1997 Study[1]

This study was completed in 1997 by Sanford et al. The methodology was thoughtful and there was an attempt to integrate two different data types (qualitative and quantitative) utilising a system known as triangulation. The results as presented did not show whether the relationships formed were significant or not. The major advantage of the study was the design of the sample as being representative of the US Population at that time. Even armed with this advantage the relationships shown in **Figure 2**(a) and (b) could not be substantiated F-Prob statistics which are not in effect significance values (should be <.05).

*Table 6: Age and distance travelled by gradient of ramp*

| Age | Slope/ distance travelled | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (years) | 0 | 1:20 | 1:16 | 1:14 | 1:12 | 1:10 | 1:8 | F-prob. |
| < 35 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | NA |
| 35-54 | 30.0 | 30.0 | 30.0 | 30.0 | 29.70 | 29.45 | 29.23 | 0.6398 |
| 55-74 | 30.0 | 29.55 | 29.76 | 29.82 | 29.48 | 29.21 | 28.89 | 0.3950 |
| > 74 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 29.53 | 0.4113 |

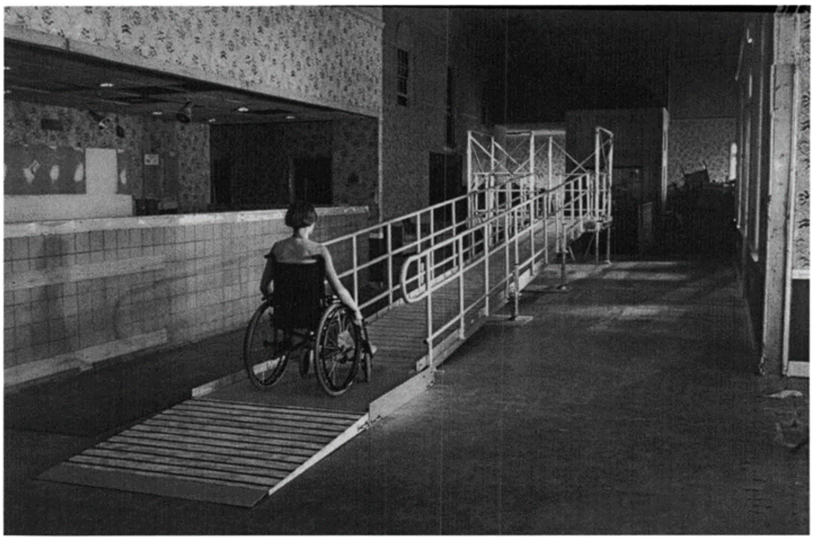

*Figure 5: Experimental Set Up of Study (Sanford et al, 1997)*

The only “obvious” relationship that was of value can be seen in Figure 2(b) with the note on the sudden increase in energy expenditure and gradient (1:8). When this compared with similar results from the more recent study (Kim et al, 2014) as set out in **Table 2** then the relationship is confirmed. Sanford et al (1997) did show that walking speeds in Figure 2(a) did not indicate any set pattern across the various mobility aids. A further study on slip resistance by Cham and Redfern (2000)[6] showed the risk associated with gradients above 1:8. The value is therefore in the comparison of the studies and the linking with other factors considered in the Desk Audit.

**THIS CONSIDERATION LED TO A CONFIRMATION OF THE MAXIMUM GRADIENT OF 1:8 AS WELL AS AN EXPANSION OF THE GRAPHICAL METHOD SPECIFIED IN C.6 OF THE ABCB DV3 HANDBOOK**

# PART TWO

# ACCESS VERIFICATION METHOD

EBEP SUBMISSION

# 1. Scope

Part 2 deals with the DV2 Verification Method for Access. As stated in Part One of this submission DV3 needs to be integrated in with DV2 for the reasons stated in Part One and where it is shown that ramps are but just form of accessway (see reference model in **Figure 1** above in Part 1**).**

The EBEP comments on DV2 may be found in subsequent sections concerned with;

- Suitability of Direction
- Verification Process
- The Equity Question
- Transparency of Occupant Characterisation Model
- Integration with FSVM
- Conclusions and Recommendations

# 2. Suitability of Direction

The EBEP Comments are as follows:

1. The overall Handbook is heading in a positive direction but needs a process structure for all the possible opportunities that will arise and require action under DV2. Each action/ solution may be a specific verification method. See separate section that addresses this issue in Section 2 of the ABCB DV2 Handbook.

2. The proposed DV2 process as described in Section 2.2 needs special attention in association with the Process Flow Chart included in Figure 2.1 of the ABCB DV2 Handbook. This applies especially to the Reference Building. The latter may work for energy assessment but requires further consideration in the light of the complex issues surrounding occupant functional ability. It is also closely linked with Occupant Characterisation and the link between this and performing at a safe level in a structured internal building environment.

   **EBEP propose that a fully completed DV2 Verification Matrix be used to drive the process as a mandatory part of the PBDB.**

3. The wording of the DV2 verification method needs to be carefully considered especially in the light of;

   a. Definition of what is accessible – do we merely adopt the NCC DtS framework otherwise the conundrum associated with egress design for DP2 – DP7 will continue.
   b. Reflecting what is required in occupant characterisation to link with the same process in the FSVM.
   c. Relationship to egressibility, wayfinding issues, signage, and the use of management processes to assist occupants especially in existing and Heritage Facilities.

4. Clear up the conflict with Egress in the light of the conundrum associated with the wording of the objectives of DP2-DP7 so that the FSVM and DV2 Processes can be more closely integrated.

5. The Dignity and Equity issues need urgent attention to avoid possible conflict with the Premises Code.

   **EBEP includes a suggested matrix of how these aspects could form part of performance solution and be written into every PBDB. This could reflect the guidance provided by an inclusive group of PBDB stakeholders adopting the focus group approach.**

In a nutshell the work on DV2 should be continued as this is a possible move and has the potential to add value in a cost-effective manner.

# 3. Verification Process

The proposed Verification Process is shown in Figure 6 below;

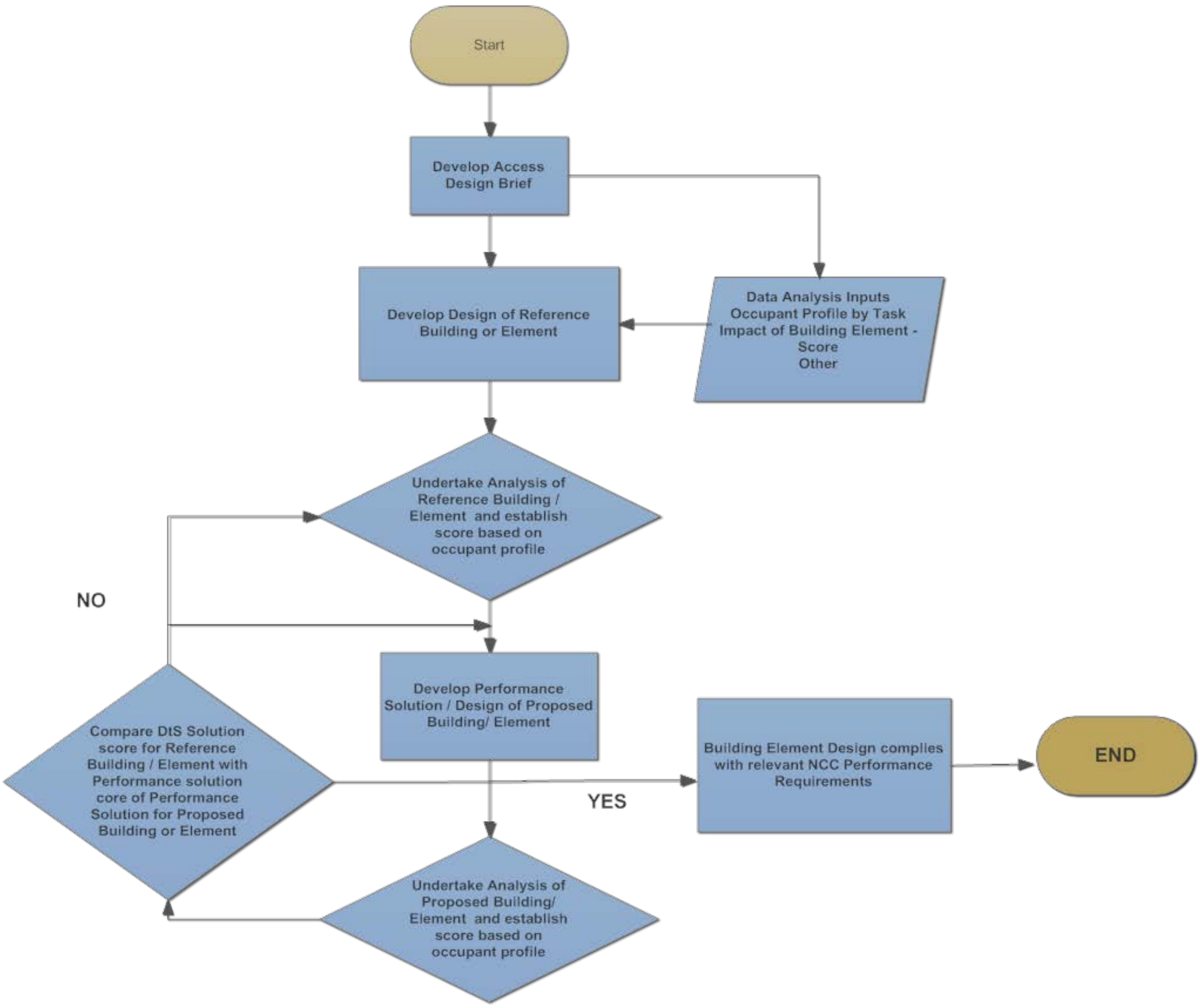


*Figure 6: Proposed DV2 Verification Process Chart*

The process flowchart in **Figure 6** requires a great deal of additional work especially in terms of;

1. Using the concept of the DV2 Performance Matrix to identify the non-compliances or opportunities and to drive the solution process – "Data Analysis Inputs"
2. Identify the point of Occupant Characterisation – "Data Analysis Inputs"
3. Reference Building Design – process step needs detailed input with section 2.2.2 of the ABCB DV2 handbook being refined to reflect the complexity of the occupant access "task" and associated building environment – "Data Analysis Inputs"
4. Occupant and environmental output scores for comparison between reference building and design building need to be developed and simplified – there is a link here with the FSVM Occupant typing and movement data – "Developing Performance Solution" steps and decision-making step.
5. DtS solution required for the reference and new design buildings – clarify in process and decision steps.
6. The process flow chart needs to identify the differentiation in methodology between elements e.g. ramps, stairs, passages, and accessible facilities manoeuvring and reach analysis.

# 4. The Dignity and Equity Question

EBEP submitted some comments on this aspect with the initial EBEP submission on the 19th January 2018. Some further comments raised by a member of the team are summarised below in the "dialogue box";

- **Equitable = access versus no access, whereas**
- **Dignity is about how you access premises free of stigma or less favourable treatment, which then flows to safety, convenience, control and enabling rather than disabling.**
- **Amenity is also important and relates to the quality of the design and hence; safety, convenience, control and enabling rather than disabling. This often equates to multiple design solutions to accommodate all users, which ultimately is more easily managed, sustainable and cost effective in the long term.**
- **Convenience is also another measure of dignity whereby an inconvenient method of entering a building = undignified access.**
- **High quality inclusive experiences and participation is the end game target.**
- **Obviously, we need to bring all this and more together in a simple framework/matrix for design analysis and assessment purposes**

A proposed design assessment matrix a sample of which is included as **Table 7** has been included for further discussion. **Table 7** has been included as an example and needs to be developed with Stage 2 of the DV2 Project.

*Table 7:* ***Equity Assessment Matrix (sample)***

***Building Entrance***

| | Unacceptable | Unacceptable except for extreme cases | Low Degree of Acceptance | Reasonably Acceptable | Acceptable | High Degree of Acceptance |
|---|---|---|---|---|---|---|
| **Equity and dignity measure** | Inequitable and undignified access | Generally inequitable and undignified access | Tolerable degree of equitable and dignified access | Reasonable degree of equitable and dignified access | Moderate degree of equitable and dignified access | High degree of equitable dignified access |
| **Equity and dignity measure** | The less favourable treatment combined with assisted access that is unsafe and unacceptable | The less favourable treatment combined with assisted access is barely tolerable | The less favourable treatment is tolerable | Reasonably convenient and independently accessible | Amenity is satisfactory and complies with the BCA/Premises Standards | Inclusive access |
| **Access description of the building element and associated matters** | A separate accessible entrance from main entrance and requires assistance with portable ramps that are too steep for independent access. | A separate accessible entrance from main entrance and requires assistance with portable ramps of satisfactory slope. | A separate accessible entrance up to 50 metres away from main entrance and requires assistance to unlock a door, operate a special lift. | A separate accessible entrance up to 50 metres away from main entrance and has manual doors with a door closer set at the max force, threshold ramp and min landing circulation spaces | The same entrance for all and has a manual door with a door closer set at the maximum force, threshold ramp and minimum landing circulation spaces | The same entrance for all users that has auto doors and level entry |

**EQUITY AND DIGNITY ISSUES NEED TO BE CONSIDERED AND INCORPORATED AS PART OF THE PBDB. ADDRESS THE SCOPE OF ACCESS – LIMITED BY DTS FRAMEWORK IN NCC D3 OR NOT?**

# 5. Transparency of Occupant Characterisation Model

At present Appendix B proposes an Occupant Characterisation Model based directly on the World Health Organisation International Classification Framework for Disability where a system for classification capabilities were developed as a generic framework for use by member countries known as the Washington Group Index. Australia has signed up for its use and has already collected data (ABS Project 4450). See **Figure 7** and **Figure 8** for sample data that can be used in the formulation of Data Inputs for the PB Design Assessment.

EBEP has also commented on the use of the ICF for Occupant Characterisation in the FSVM. Their characterisation concentrates on emergency evacuation ability. The basis of the Occupant Characterisation Model is discussed in Appendix B centred around the details shown in Figure 3.5 of the ABCB DV2 Handbook. This is the same model used in the FSVM proposal.

The FSVM was quite helpful in that it suggested an appropriate level of "design ability" which is the mean of "severe and profound". The data available from ABS Project 4450 (e.g. **Figure 7** and **Figure 8** below) can be used to establish the level of ability for each type of disability except that additional analysis will be required for MWC and PWC Users so that is another reason for the inclusion of the DV3 analysis with DV2 along with the need for the validated input data shown in **Table 4** and **Table 5**.

**THE DESIGN OCCUPANT CAPABILITY FOR EACH DISABILITY COULD THEREFORE BE SET AT THE MEAN OF SEVERE AND PROFOUND AFTER THE COMORBIDITY CHECK IS APPLIED.**

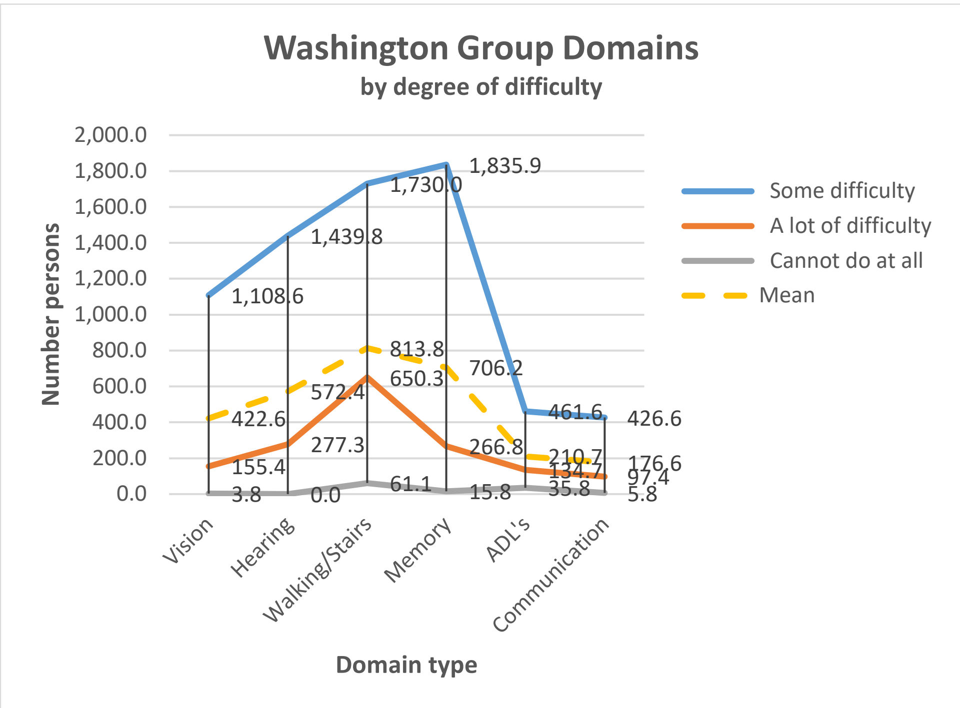


*Figure 7: Degree of Difficulty with tasks*

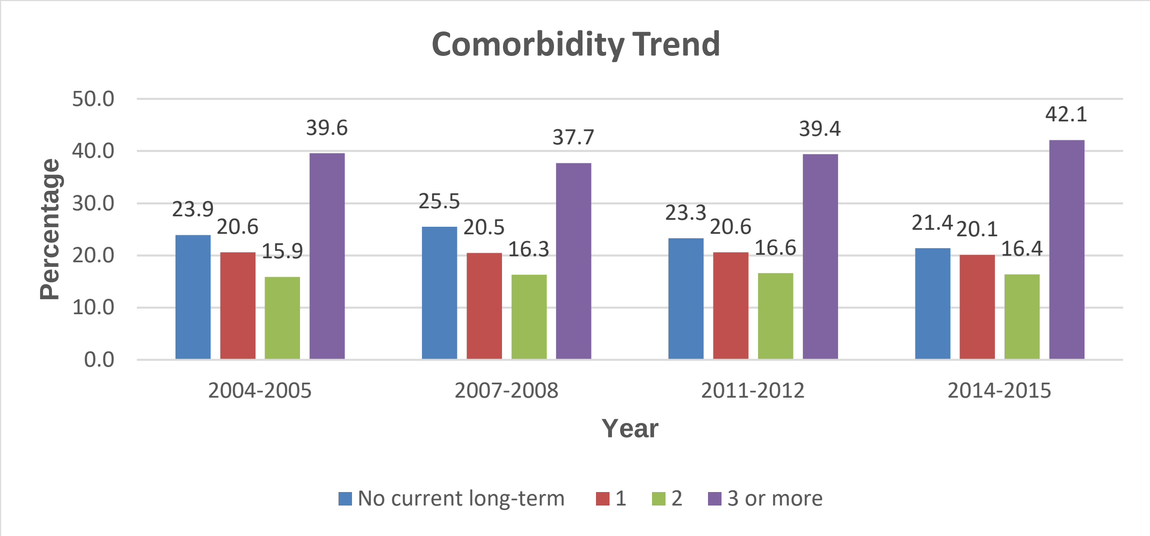


*Figure 8: Comorbidity Trend – Apply to Figure 7 outcomes and increase level of difficulty*

# 6. Integration with the FSVM

The FSVM calls up the ICF Framework (see **Figure 9** below) and yet does not apply it correctly. As the fire grows the environment changes due to increased heat, decrease in visibility and increase in toxic gases. A simple RSET/ASET analysis is no longer suitable.

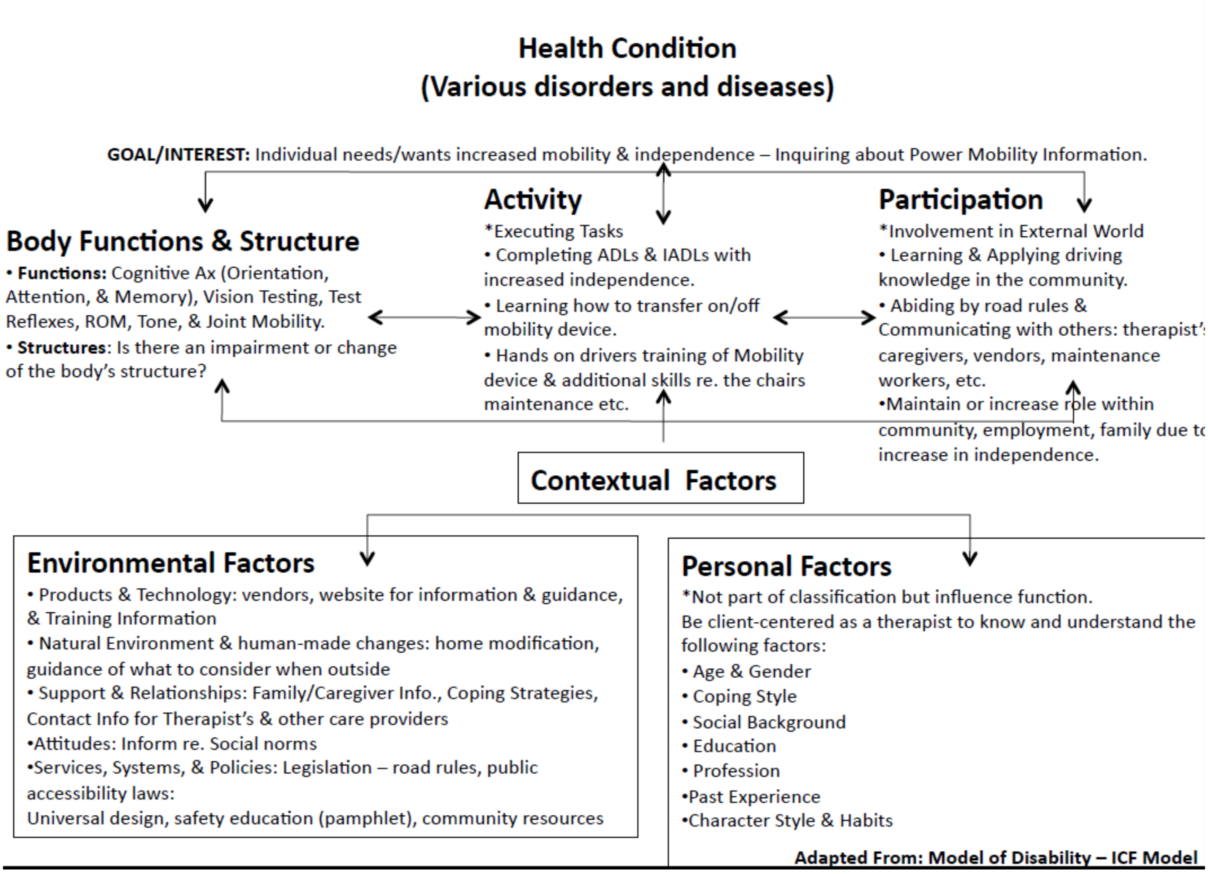


***Figure 9: The ICF Disability Model** – FSVM ignores the impact between environment and the level of evacuation activity in the development of the fire.*

A common Occupant Characterisation approach between DV2 and FSVM is therefore essential. Each type of disability needs to be characterised in line with the Model set out in Appendix A5 of the EBEP DV2 Access Submission. This will allow a transparent occupant-based assessment to be undertaken of the interaction between ALL[12] the factors noted in the ICF Disability Model shown in **Figure 9** above.

**OCCUPANT CHARACTERISATION MODEL FOR FSVM/ DV2 NEED TO BE COMPATIBLE AS COMPLYING WITH DP2-DP7 IN THE MAIN – DEVELOP COMMON OUTPUT SIMILAR IN APPROACH TO THAT OF DV2.**

# 7. Conclusions and Recommendations

The most important suggested change to DV2 and DV3 is that of gradient, where the maximum gradient should be 1:8. Research does not support anything greater than that. Also, the accessibility framework shown in **Figure 1** strongly suggests that a simpler assessment matrix that has been validated by a more up to date study (Sanford et al, 1997 vs. Kim et al, 2014 combined with others[2,5,6]) could be used as a default with DV2. Sanford[1] and Kim[8] support each other with Kim[8] confirming some of the subjective findings in Sanford[1].

The default matrix in Part 1 reflects this. Dignity and Equity issues need to be incorporated into the DV2 Assessment Process which will make them more inclusive and improve the Amenity. A suggested approach is discussed in Section 4 with the outcome reflected in **Table 7**.

An extremely positive outcome was found in the comparison of the Occupant Characterisation Process for DV2 and the FSVM. Both documents used the same source material from which plentiful and significant data is available and can be assembled[13]. The process needs to be simplified from that shown in the current DV2 proposal. This does not mean that the FSVM outcome should be adopted for "typing design persona".

**EBEP recommend as follows;**

1. **EBEP propose that a fully completed DV2 Verification Matrix be used to drive the process as a mandatory part of the PBDB.**
2. **No accessway shall have a gradient exceeding 1:8 which is what was recommended in the EBEP DV3 Submission on Ramps in the Executive Summary.**
3. **The graphical method suggested in the EBEP DV3 Submission on Ramps (C6 of current DV3 Document) should be replaced with the matrix outlined in Table 4 and Table 5 as part of DV2 and that these tables act as default values.**

[12] An example of this relates to visibility. The FSVM does analyse the surrounding atmosphere (species assessment) but does not match this with visual impairment factors (visual acuity and visual field). Such an analysis could be simplified via the creation of a suitable matrix which adjusted the visual factors in accordance with the level of "visibility" attributed to the level of soot in the atmosphere. The matrix could also include the occupant characteristics to be included for toxic gas ($CO_2$ /CO concentration) concentrations.

[13] ABS Data Builder referring back to the design and structure of the WHO Washington Group Questionnaire.

**4.** **Integrate DV3 in with DV2 as part of the Stage 2 process with the "engineering assessment" being used to validate the design derived from the Default Tables. Alter the DV3 process to incorporate the DV2 Occupant Characterisation Model.**

**5.** **Incorporate the dignity and equity design issues as discussed in Section 4 using Table 7 as the template for a rating table for each DV2 solution.**

**6.** **Consider the question raised in proposed DV2 Verification Matrix of the extent of accessibility in each facility of the DtS definition in NCC D3 being applied.**

**7.** **Occupant characterisation model for FSVM/ DV2 need to be compatible as complying with DP2-DP7 in the main – develop common output similar in approach to that of DV2.**

# APPENDIX

## VIBRATION CONSIDERATIONS

This section has been included to add weight to the proposed DV3 Default Verification Matrices as shown in Tables 4 and 5.

The reference seminal article is Wolf, E., Cooper, R.A., Pearlman, J., Fitzgerald, S.G., and Kelleher, A., (2007), Longitudinal assessment of vibrations during manual and power wheelchair deriving over select sidewalk surfaces, *JRRD*, Vol. 44, No.4, pp. 573-580.

The sidewalk surfaces are shown and described in "Figure 2" in the article as it appears on page 576:

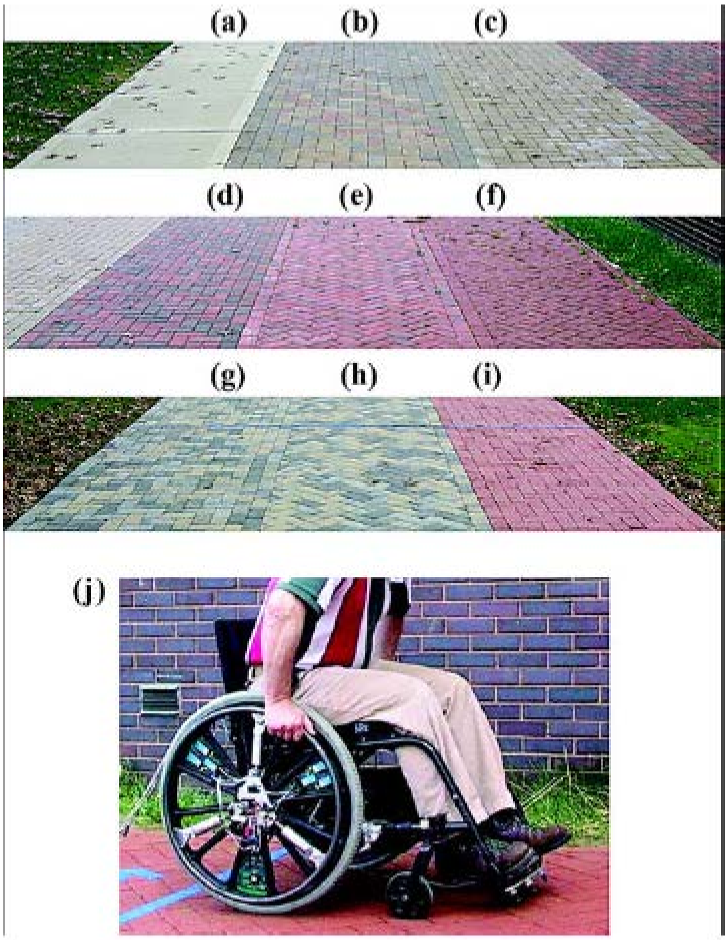


**Figure 2.**
Surfaces tested: (a) 1 (poured concrete), (b) 2 (concrete, no bevel), (c) 3 (concrete, 2 mm bevel), (d) 4 (concrete, 8 mm bevel), (e) 5 (brick, 4 mm bevel), (f) 6 (brick, no bevel), (g) 7 (concrete, 6 mm bevel), (h) 8 (concrete, 6 mm bevel), and (i) 9 (concrete, 4 mm bevel); (j) setup of Quickie® GP manual wheelchair (Sunrise Medical, Carlsbad, California).

The abstract from the article describes the study succinctly;

Wheelchair users rely on their wheelchairs for mobility for extended periods of time every day. According to the International Standards Organization 2631-1 standard on human vibration, individuals in a seated position when exposed to whole-body vibrations (WBV) are at risk of injury.
This study evaluated vibration exposure during manual and power wheelchair driving over nine sidewalk surfaces and differences in vibration exposure over 3 years. Ten nondisabled subjects were asked to drive a manual wheelchair at 1 m/s and a power wheelchair at 1 m/s and 2 m/s over nine sidewalk surfaces while WBV were measured at the seat and footrest of the wheelchair. At 1 m/s, significant differences existed between
surfaces and years at both the seat and the footrest for the manual and power wheelchair users. At 2 m/s, significant differences existed between surfaces and years at the seat and the footrest for power wheelchair users. Our results show that both manual and power wheelchair users may be at risk for secondary injuries from WBV when traveling over certain surfaces.

The graph overpage being Figure 1 from the article is a modified version of the graph in Figure B.1 of ISO 2631-1: 1997 referred to in the article. Any vibration >1m/s$^2$ is considered to be unacceptable and would correspond to a high rating on the Borg Scale similar to that in Kim et al (2014)[8].

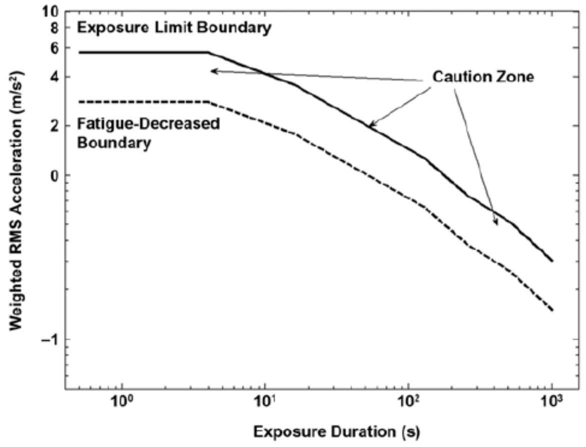


**Figure 1 from Wolf et al (2007) as cited on the previous page**

*Table 8: Extract from Wolf et al (2007) – Table 2*

Specifications of surfaces tested.

| Surface | Name | Edge Detail | Composition | Dimension (mm) | | | Installed Pattern |
|---|---|---|---|---|---|---|---|
| | | | | Length | Width | Height | |
| 1 | Poured Concrete* | — | Concrete | — | — | — | Smooth |
| 2 | Holland Paver | Square (no bevel) | Concrete | 198 | 98 | 60 | 90° |
| 3 | Holland Paver | 2 mm bevel | Concrete | 198 | 98 | 80 | 90° |
| 4 | Holland Paver | 8 mm bevel | Concrete | 198 | 98 | 60 | 90° |
| 5 | Whitacre-Greer | 4 mm bevel | Brick | 204 | 102 | 57 | 45° |
| 6 | Pathway Paver | Square (no bevel) | Brick | 204 | 102 | 57 | 45° |
| 7 | Holland Paver | 6 mm bevel | Concrete | 198 | 98 | 60 | 90° |
| 8 | Holland Paver | 6 mm bevel | Concrete | 198 | 98 | 60 | 45° |
| 9 | Holland Paver | 4 mm bevel | Concrete | 198 | 98 | 60 | 90° |

*Control surface.

Surface 1 comprising concrete with a broom finish was taken as the "control" surface as this surface was seen as being a standard for footpaths (sidewalks). The details of the slip resistance determined by the wet pendulum test. This surface has a slip resistance classification of P5 tested under wet conditions. It is therefore an ideal surface condition for Australian conditions.

| | | | | |
|---|---|---|---|---|
| Broomed finish Class 5/6 or wood float (U2) | 0.65 Minimum | 60 (PTV) P5 | 0.85 Maximum | 73 (PTV) P5 |

The WBV values shown in **Table 9** and **Table 10** show that the best surface, surface 2 (Concrete paver with no bevel) recorded the least WBV at the seat and footrest. Surface 4 (concrete with the 4mm bevel) and surface 7 had higher WBV's at the seat and footrest. These differences were significant (p<.05).

The study concludes;

*"These results demonstrate that some ICP surfaces should be considered for wheelchair access routes and may reduce the amount of WBV transmitted to wheelchair users, specifically the surfaces with the smallest bevels. The results clearly show that many of the interlocking paving unit surfaces are as good if not better than the standard poured concrete surface at reducing the amount of WBV transmitted to wheelchair users. Additionally, some surfaces may produce levels of WBV exposure that could cause secondary injuries to both manual and power wheelchair users over time."*

**Page 578 Wolf et al (2007)**

*Table 9: Extract from Wolf et al (2007) – Table3 – WBV Values – Wheelchair Seat*

Root-mean-square vibration (mean ± standard deviation) for wheelchair seat for manual wheelchair and power wheelchair at 2 different driving speeds for year 3.

| Surface | Manual Wheelchair (1 m/s) | Power Wheelchair (1 m/s) | Power Wheelchair (2 m/s) |
|---|---|---|---|
| 1 | 0.47 ± 0.07 | 0.37 ± 0.09 | 1.17 ± 0.21 |
| 2 | 0.32 ± 0.06* | 0.28 ± 0.06* | 0.60 ± 0.12* |
| 3 | 0.39 ± 0.07* | 0.33 ± 0.08 | 0.67 ± 0.12* |
| 4 | 0.76 ± 0.16† | 0.85 ± 0.19† | 0.89 ± 0.14* |
| 5 | 0.46 ± 0.09 | 0.33 ± 0.10 | 0.75 ± 0.15* |
| 6 | 0.47 ± 0.08 | 0.37 ± 0.09 | 0.90 ± 0.14* |
| 7 | 0.59 ± 0.09† | 0.59 ± 0.08† | 0.76 ± 0.10* |
| 8 | 0.78 ± 0.09† | 0.38 ± 0.05 | 0.89 ± 0.15* |
| 9 | 0.48 ± 0.06 | 0.40 ± 0.05 | 0.66 ± 0.08* |

*Surfaces resulted in significantly lower whole-body vibrations (WBV) ($p < 0.05$) than surface 1.
†Surfaces resulted in significantly higher WBV ($p < 0.05$) than surface 1.

*Table 10: Extract from Wolf et al (2007) – Table 4 – WBV Values – Wheelchair Footrest*

Root-mean-square vibration (mean ± standard deviation) for wheelchair footrest for manual wheelchair and power wheelchair at 2 different driving speeds for year 3.

| Surface | Manual Wheelchair (1 m/s) | Power Wheelchair (1 m/s) | Power Wheelchair (2 m/s) |
|---|---|---|---|
| 1 | 1.36 ± 0.22 | 0.53 ± 0.10 | 1.26 ± 0.31 |
| 2 | 0.81 ± 0.18* | 0.32 ± 0.08* | 0.67 ± 0.21* |
| 3 | 1.09 ± 0.23* | 0.38 ± 0.09* | 0.79 ± 0.19* |
| 4 | 2.30 ± 0.44† | 0.66 ± 0.16† | 1.21 ± 0.28 |
| 5 | 1.34 ± 0.32 | 0.43 ± 0.09 | 0.84 ± 0.21* |
| 6 | 1.41 ± 0.25 | 0.47 ± 0.09 | 0.94 ± 0.23* |
| 7 | 1.79 ± 0.29† | 0.43 ± 0.08 | 0.78 ± 0.70* |
| 8 | 2.19 ± 0.32† | 0.46 ± 0.13 | 0.86 ± 0.26* |
| 9 | 1.35 ± 0.18 | 0.32 ± 0.06* | 0.67 ± 0.16* |

*Surfaces resulted in significantly lower whole-body vibrations (WBV) ($p < 0.05$) than surface 1.
†Surfaces resulted in significantly higher WBV ($p < 0.05$) than surface 1.

**The values shown in the proposed default DV3 VM Matrix (Table 4 and Table 5) therefore satisfy the results of the study (Wolf et al, 2007) but should other surfaces be proposed with a profile variation > 2mm then the system should be subject to detailed DV3 assessment.**

**COMMENTS**

**TO**

**AUSTRALIAN BUILDING CODES BOARD**

**April 2018**

# RESPONSE 3

# NCC 2019

# FIRE SAFETY VERIFICATION METHOD

PROVIDED BY:

**ENABLING BUILT ENVIRONMENT PROGRAM**

**Faculty of Built Environment**

**UNSW – Sydney**

# 1. Structure of Response

The structure of this response relates mainly to catering inclusively for the needs of the occupants in event of fire. Based on this as a focus the structure of our response is as follows;

- Introduction (mentioning the NZ experience with C/VM2[1])
- FSVM Process – Focussing on Egressibility
  - Generally
  - The FSVM Process
  - Overview of DP2-DP7 issues – accessible egress or not?
  - Comments on Occupant Characterisation and the need for common link with DV2.
  - Defining RSET
    - The Framework
    - Warning
    - Pre-travel
    - Movement and ability – challenges, speeds, capability, exit types etc.
- Conclusions and recommendations

# 2. Introduction

It is interesting to note that egress performance is closely linked to access by the mere wording of the relevant performance clauses[2]. If we examine the various DtS requirements in Sections D and E of the NCC 2016, it appears that most of the egress requirements do not include occupant types addressed in D3 and yet the performance clauses do as shown in **Table 1** below. If the wording is to remain as it is then special instructions need to be provided within the verification procedure as to the method to be adopted for the occupant types in **Table 3** via **Table 2**. The typologies developed are based on the WHO Washington Group Classification procedure outlined in detail in the EBEP DV2 Handbook Submission entitled "Access to and Within a Building". EBEP has developed a typology that link Sections 5.5 and 5.6 of the FSVM to the DV2 Procedure.

[1] Ministry of Business, Innovation and Employment, (2014), C/VM2, Verification Method: Framework for Fire Safety Design, For NZBC Clauses C1-C6 Protection from Fire, Amendment 5. See also associated commentary. Documents referred to in this Response as NZC/VM2 and NZCOM.

[2] See EBEP DV2 Handbook Matrix Diagram where the linkage is shown in greater detail.

*Table 1: Performance Clauses and Occupant Capability*

| Performance Clause | DV2 Connection | | RSET Parameters | | | |
|---|---|---|---|---|---|---|
| Number | Keywords | DV2 Issue | Response Capability | Pre-travel | Movement | Evac Strategy |
| DP2 | Move safely | Circulation | NA | NA | Mobility/ wayfinding ability | Functional limitation |
| DP3 | Move safely / protection from falling | Escape and circulation | NA | NA | Functional limitation – falling and mobility | NA |
| DP4 | Evacuate safely to exits | Capability (exit type – suitability) | NA as concerns Exits | Exit wayfinding info | Mobility and wayfinding ability | Exit type related to occupant type |
| DP5 | Exit type – fire isolation | Occupant type and capability – exit type | NA as concerns FI of exits – exiting time considerations | Exit type – could be refuge – do occupants trust the approach?**Error! Bookmark not defined.** | | Links with DP4 makes occ. type an issue |
| DP6 | Path of travel – length and wayfinding issues - signage | Path of travel could be an accessible route | NA | Familiarity – length of time to orientate and degree of response practice | | Length of time – severe limitations e.g. Type C occupant |
| DP7 | Lifts for evacuation ***(No tangible benefit for use in performance solutions when no concessions are granted for other egress elements)*** | Vertical egress speed shown in Table 12 of FSVM as "0". Assumes use of lifts or refuges. | Knowing their options. Value of PEEPS[3]. | Knowing their options. Value of PEEPS[4]. | Can only use lifts or evacuation chairs for descent down stairs. No mention made of refuge spaces. Could extend landings in stairs. | Cannot be used in lieu of complying exit? Refuge or defend in place? |
| EP4.1 | Smoke management for visibility of egress system | Measures of visibility commensurate with degree of vision impairment | Degree of familiarity with scenario will trigger appropriate behaviour. This applies especially with older persons. | Awareness issues with visibility level forecast | Smoke management capability plus Use of signage or route marking systems such as those used for access that will compensate for lack of visibility | Suggested that a system that familiarises occupant with evacuation procedure PEEPS. |
| EP4.2 | Egress route signage and exit signage | Same principle as for accessibility – contrast and legibility. | Depends on degree and type of impairment *(e.g. vision may require greater contrast luminance for signage)* | Standardised exit signage has been extensively tested. Valuable data in Exodus Model | Signage placement will depend on occupant wayfinding ability where path of travel is complex. | Suggested that a system that familiarises occupant with evacuation procedure PEEPS. |
| EP4.3 | Alarm | NA | Visual or audible | Thomas and Bruck on Audible signature and clarity of visual for degrees of | NA | Occupants do not respond immediately. Will also depend on familiarity. |

[3] Case study of Zmud (2007)[4] as well as improving egressibility (Robbins and Warren, 2015)**Error! Bookmark not defined.**.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | vision impairment | | |

*See **Table 2** and **Table 3** below for confirmation that Occupant characterisation should include capability issues (functional limitations).*

Rather than shelve the issues there is an opportunity that we could explore to develop a meaningful FSVM that follows evidence based research on "soft" design aids that would promote occupant familiarity with the building especially in event of emergency. Before doing so preliminary research carried out in New Zealand may provide some direction. The research topic was "accessible egress"**Error! Bookmark not defined.**. Robbins and Warren (2015) use the term "egressibility" to classify the appropriateness of a building egress system to satisfy the "needs" of the occupants in terms of their "type" as defined in the FSVM and present a very concise summary

"The results indicate that the issues related to occupant egressibility expectations and experiences include:

- Assumptions of areas of refuge being located at all/any stairs or in front of all/any elevators.
  This may lead to individuals needing to be searched for or overlooked and leads to inconsistent identification of areas of refuge and instructions for use.
- The need for consistent training of wardens.
- The need for familiarity of users and operators with evacuation assistance devices.
- A general level of misunderstanding about some fire safety systems and how they work. However, there being a generally positive view of their presence. For example, believing a sprinkler system operates throughout a building based on a misrepresentation in movies and other entertainment may cause undue worry."

***Table 2: Occupant Characteristics/ Capability – Link to DV2 Procedure***
*Source: Table 10 FSVM*

| ***Core activity limitation*** | ***Prevalence 000's*** | ***% of Australian population*** | ***% of building population*** |
|---|---|---|---|
| Hearing impairment mild – moderate (total) | 2670 (97% of total) | 12.5% | 12 |
| Hearing: Severe - profound impairment (thresholds > 65dB) | 80 (3% of total) | 0.3% | 1 |
| Vision impairment total | 357 | 1.6% | 1.5 |
| Vision: Severe impairment (Low Vision) | 322 | 1.45% | 1 |
| Vision: Profound impairment (Blind) | 35 | 0.1% | 1 |
| Mobility impairment | 693 | 3% | 3 |
| Mobility: Profound – Disability Aids (total) | 630 | 2.9% | 3 |

***Table 3: Occupant Typologies – Link to DV2 Procedure***

*Source: Table 11 FSVM*

| ***Critical state*** | ***Mobility*** | ***Mobility*** | ***Hearing*** | ***Hearing*** | ***Vision*** | ***Vision*** |
|---|---|---|---|---|---|---|
| | **None** | **Severe/ Profound** | **None** | **Severe/ Profound** | **None** | **Severe/ Profound** |
| awake and familiar with the building | A | C | A | B | A | B |
| awake but unfamiliar | B | C | A | B | B | C |
| likely to be asleep | B | C | B | C | B | C |

Robbins and Warren (2015)**Error! Bookmark not defined.** suggest the following to address the major findings;

- Providing opportunities for experience of and familiarization with the use of intended evacuation assistance devices in non-emergency situations. This includes experiential planning for what happens at the bottom of the stairs, etc. where the person's personal mobility device is no longer with them.
- Including individuals who may require assistance in evacuation drills, so that both users and operators of intended evacuation devices gain experience of and confidence in the equipment and each other.
- Additional requirements to complement current regulation for the clear identification of areas of refuge and provision of instructions for their use.
- Public education on the identification of areas of refuge areas and intended use.
- Standardized training of wardens, including how to offer and provide assistance to accommodate the range of needs of building occupants, and information to collect and provide to the Fire Service.
- Public education about what to expect from a warden and general information on offering and providing assistance to others.

The value of this approach is summarized by Zmud (2007) in connection with her own contribution to the "egressibility" of Tower 2 in the 9/11 Incident[4]. The occupant was a middle aged female quadriplegic located above the 80th level at the time of the incident. Her employer was committed to employee health and safety and motivated their employees to attain a reasonably high level of fire safety awareness. The female occupant purchased her own "evacuation" chair and regularly participated in trial evacuations every six months. She and a group of workmates formed themselves into a team where the other team members acted as "buddies". They became experts at assisted evacuation. The subject occupant survived the incident as they started to evacuate at the initial alarm. She passed many other wheelchair users on the way down the stairs who were not prepared and practiced. The others did not survive. Experiential learning is invaluable and can be reinforced via a system of PEEPS[5]. It could be argued that such an approach could be used as part of a FSVM. There are systems in place in New South Wales and Queensland as well as other States that have systems in place to enforce/ maintain such an approach on a yearly basis. The writer has already followed this process in practice and can provide additional detailed evidence of its value.

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[4] Zmud, M., (2007), *Public Perceptions of High Rise Building Safety and Emergency Evacuation Procedures Research Project*, The Fire Protection Research Foundation, NFPA.

[5] Personal Emergency Evacuation Plans

# 3. FSVM Process – Focusing on Egressibility

## 3.1 Generally

The section of the FSVM entitled "How to use this Document" contains a summary of the FSVM process spread over some seven items. The documentation process for the PBDB is further described in Section 2 and the development of the associated fire safety strategy in Section 3. Many of the other proposed verification methods/ processes are based on a flow chart where the interconnecting logic and decision making sequence is described. This approach is visual and simple. This FSVM does not utilise this approach whereas the New Zealand FSVM (C/VM2) does. The NZ equivalent is shown in **Figure 1** below.

## 3.2 The FSVM process – overall comments

An initial comparison shows that the process in the FSVM is equivalent to that in the NZ C/VM2 Document except that Design Scenario UF[6] does not make sense. It would appear that the number of Design Scenarios could easily be rationalised so that only 10 have to be considered. The other issue which is discussed further below via Tables 1-3 and Table 4 below:

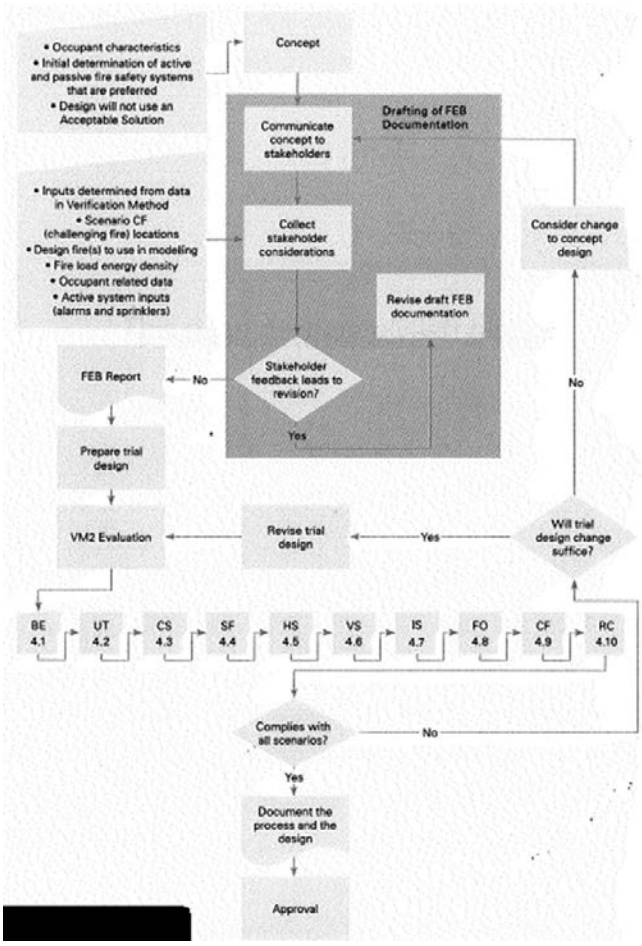


*Figure 1: NZ C/VM2 PBD Process*

A thorough examination of Section 3 reveals a problematic design process where the PBDB is not used to its full potential unlike what was promoted in the International Fire Engineering

[6] This comment is based on the description outlined in Section 6.12 of the FSVM

Guidelines. The flow chart shown in **Figure 1** quite clearly shows that the Fire Safety Strategy is an integral part of the PBDB. The identification, selection and assembly of the inputs, modelling procedures, emergency services' requirements, and especially the characterisation of occupants[7] can therefore be addressed and agreed before commencing design. This would avoid confusion during Design Development and Contract Documentation Stages. Inclusion of a meaningful flow chart would clarify this and strengthen the reliability of the design outcomes for each scenario. This is clearly shown in the shaded area of **Figure 1** entitled "Drafting of the FEB (PBDB) Document". The flow chart also shows the connection between the physical aspects of "trial designs" developed during the concept/ design development stages where a trial design may need to be changed.

## 3.3 Overview of DP2-DP7 Issues – Accessible Egress or not?

This section should be read in conjunction with **Table 1**. The equivalent DtS provisions do **not** cater for the full range of occupant characteristics. DV2 relies on this conundrum being addressed or the whole issue of access being revisited.

Flow Charts are proposed for DV2 and DV3 which are related to Access. The ABCB DV2 Handbook proposal shows how Egress and Access are closely linked by the DP clause wording. The intent of DP4, DP6, and DP7 relating to the characteristics of the occupants is clearly established especially via a suggested but incomplete procedure identified in Tables 10 and 11. The reader is referred to Appendix B of the ABCB Consultation Document "Access to and within a building" where a detailed suggested Occupant Characterisation method based on the Washington Group Model[8] is proposed. At present the status of the Egress Performance Clauses needs urgent attention as the Occupant Characterisation Method set out in Sections 5.5 and 5.6 is inconsistent with these clauses where the DtS requirements do not reflect the disabilities at all in terms of egress research such as that of Robbins and Warren (2015)**Error! Bookmark not defined.**, Spearpoint and MacLennan (2012)[9] and Chen et al (2018)[10] relating to response, pre-travel time and movement. This will be discussed in detail in a subsequent section together with the lack of any tangible benefit associated with DP7 where no concessions are granted for other egress elements such as exits.

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[7] This is especially important given the importance of inclusivity. At present there is none and yet there are signs of this as demonstrated in **Table 2** and **Table 3**.

[8] Madans JH, (2014) *Washington Group on Stability Statistics*, Power Point Presentation, National Center for Health Statistics / Washington Group on Disability Statistics, WHO. Questionnaire and Model at an international level where the data on disabilities is consistent and comparable across most countries and can be gathered in the same manner via Population Census. Refer http://unstats.un.org/unsd/statcom/doc12/2012-21-WashingtonGroup-E.pdf for further detailed information.

[9] Spearpoint M and MacLennan HA, (2012), The effect of an ageing and less fit population on the ability of people to egress buildings, *Safety Science*, Vol. 50, No.8, pp. 1675-1684, DOI10.1016/j.ssci.2011.12.019

[10] Chen J, Wang J, Wang B, Liu R, and Wang Q, (2018) An experimental study of visibility effect on evacuation speed on stairs, *Fire Safety Journal*, Vol. 96, pp. 189-202. Read in conjunction with MacLennan (2013) PhD Thesis (30 yr. longitudinal study on multiple flight stair descent), University of Salford, USIR; Robbins and Warren (2015)**Error! Bookmark not defined.** and Elliott DB, Foster RJ, Scally AJ, and Buckley JG, (2015), Analysis of lower limb movement to determine the effect of manipulating the appearance of the stairs to improve safety: a linked series of laboratory-based, repeated measures studies, *Public Health Res*, Vol. 3 No. 8. DOI: 10.3310/phr03080.

**Table 1** summarises the conundrum introduced above. The FSVM process for building egressibility is therefore in question and this would be highlighted even further if a process flow chart such as that shown in **Figure 1** were to be adopted.

It can be concluded from this overview that the structure and content of the Egress section of the FSVM itself is what creates the conundrum. If the latter is not addressed then the Code may be "unusable" in the field.

## 3.4 Comments on Occupant Characterisation and the Design Occupant

"Design Occupant" is similar to the concept adopted in Chapter 7 of the Warren Centre Fire Engineering Report. Occupant "ability" was also included. The "occupant typing" in the characterisation model described in Section 5.5.2 of the FSVM relies heavily not on only on the ABS Survey of Disability, but a further supplementary survey[11] based on the Washington Group System referred to in Section 3.3 of this submission. The disabilities that should be addressed are those which have been classified as such via the WHO's Model of "International Classification and Functioning and Health" (ICF). The disabilities now include dementia and obesity.

Spearpoint and MacLennan (2012)[9] illustrate the impact of ageing and a sedentary life style on occupants which is not really addressed in the "Occupant Profiles" to the extent that it should. By the year 2030 the number of persons over 65 years will be 1 in every five giving a total population of 5.7 million persons of which 10%+ can be expected to have dementia. Morbid Obesity, which refers to an individual that is at least 50-100% above their normal mass, is expected to increase to more than 1 in 4 adults in 2030. MacLennan (2013)[12] showed how obesity can impact balance and movement speed especially in stair descent with descent speeds falling below 0.5m/s. Dementia and Obesity are not reflected to the level they should in 5.5.2 of the FSVM.

Occupant grouping in Table 10 of the FSVM does not reflect dementia and obesity. An evidence-based egress model is available[13] and could be adopted for use with the FSVM. The occupant functional limitations noted on Figure 2 need to be adopted in Table 10 and reflected also in Table 11 of the FSVM and should also be expanded to include children.

The Design Occupant therefore needs have their abilities reclassified (typed) to reflect their egress status i.e;

- Response ability and time – to a warning where the mode of communication needs to reflect the needs of the "design occupant characteristic" (visual/tactile, audio/ frequency/ volume and signature[14] and their associated cognitive status/ level of awareness – asleep or awake[14]). PD7974-6 rates the quality of the warning types as explained in Annexure A of that document. These do recognise response capability but is still non-inclusive when the full range of occupant functional limitations are taken into account.

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[11] Australian Bureau of Statistics, Project 4450.0, available on https://www.abs.gov.au/ausstats/abs@.nsf/mf/4450.0

[12] MacLennan (2013) PhD Thesis (30 yr. longitudinal study on multiple flight stair descent), University of Salford, USIR. Also refer EBEP/ UNSW submission to ABCB on stairs for DV4 Handbook (Stages 1 and 2).

[13] As described in Spearpoint and MacLennan (2012). This Model, suitably adapted, is used in the field by Fire Engineers such as HolmesFire in Australia.

[14] Bruck D and Thomas I, (2008), Fire Safety Science–Proceedings of the Ninth International Symposium, pp. 403-414, DOI:10.3801/IAFSS.FSS.9-403. Although FSVM Section 5.6.3 mentions this type of fire alarm signal it does not cover all occupant types such as children, older persons especially those with dementia, those with depression under medication and those with other cognitive issues.

- Pre-travel or preparation time – function of how familiar the occupant is with the warning, egress system and evacuation procedure[4]
- Movement and wayfinding – familiarity with procedures and also degree of mobility decision making about wayfinding


*Figure 2: Functional Limitations, the enabling model*

The abilities will change for each of these phases. The female person in the 9/11 case study demonstrates this as follows;

- Warning: No hearing impairment – heard the alarm/ warning
- Pre-travel: Because she had practiced her response she was familiar with her response and her group of colleagues/ buddies gathered around immediately. Her evacuation aid was readily accessible and set up by the group so that the pre-travel time would have been a minimum which shows up a flaw in the "occupant typing" which is the impact of assistance and evacuation practice. NSW has a control process that can be used with PEEPS known as the "critical fire safety feature" and Queensland can accommodate this approach fire their Fire Safety Act. Similar provisions exist in Southern and Western Australia.
- Movement – She as part of the evacuating group was able to be transferred to the evacuation chair and moved to the stair and then descend to ground level. Research in this type of stair descent, when practised, shows that the "group" evacuating with the evacuation chair occupy the same amount of space as other occupants and descend at the same speed as other groups.

It is interesting to note that in the NZ C/VM2 document that a link to BSI PD7974 Part 6 (Human Factors – Life Safety Strategies – Occupant evacuation behaviour and condition) which appears to underpin the "Design Occupant" typing in C/VM2 and the proposed FSVM. PD-7974-6 discusses the concept of "Design Behavioural Scenarios" where the Design Occupant interfaces with the egress system. PD7974-6 uses the term behavioural modifiers that are reflected in the typical scenarios. One of these modifiers that is the most significant for the Design Occupant is the impact of the level of fire safety management in the building regardless of the classification. PD 7974-6 sets down three levels (M1-M3). M1 is the highest quality where the management process and style is regularly audited and where the process is inclusive[15]. M3 is where the level of management is virtually non-existent. MacLennan (2013) showed the impact of M1 in his own extensive 30 year study of trial evacuations. This shifts the Design Occupant from being unfamiliar with the fire alarm and the evacuation procedure to one of being familiar. It also highlights the lack of innovation evidenced in **Table 4.**

| **Design Scenarios** | *Provision of Traditional Exits* ***DP4*** | *Fire isolation of Traditional Exits* ***DP5*** | *Paths Of Travel – DP2 too* ***DP6*** | *Evacuation Lifts – no concession* ***DP7*** | *Auto Warning* ***EP2.1*** | *Visibility Escape Path* ***EP2.2*** | *Emerg. Lifts* ***EP3.2*** | *Emerg. Lighting* ***EP4.1*** | *Emerg. Signage Exit Signs* ***EP4.2*** | *Alarm Notification* ***EP4.3*** |
|---|---|---|---|---|---|---|---|---|---|---|
| BE | YES | YES | YES | YES | YES | YES | NO | YES | YES | YES |
| UT | YES | YES | NO | NO | YES | YES | NO | YES | YES | YES |
| CS | YES | YES | YES | NO | YES | YES | NO | YES | YES | YES |
| SF | YES | YES | YES | NO | YES | YES | NO | YES | YES | YES |
| IS | YES | YES | YES | NO | YES | YES | NO | YES | YES | YES |
| CF | YES | YES | YES | NO | YES | YES | NO | YES | YES | YES |
| RC | YES | YES | NO | YES | YES | YES | NO | YES | YES | YES |
| SS | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| HS | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |
| VS | NO | NO | NO | NO | NO | YES | NO | NO | NO | NO |
| FI | NO | YES | NO | NO | NO | YES | YES | NO | NO | NO |
| UF | NO | NO | NO | NO | NO | NO | NO | NO | NO | NO |

** **DP2 (Safe movement) should have been included as it refers to stairs and ramps, paths of travel, surfaces etc. It ties in closely with DV2 (accessibility) so please consult DV2 Matrix for further detail.***

## Design Scenario Legend:

**BE** Blocked Exit (Design Scenario)
**CF** Challenging Fire (Design Scenario)
**CS** Concealed Space (Design Scenario)
**FI** Fire brigade Intervention (Design Scenario)
**HS** Horizontal fire Spread (Design Scenario)
**IS** Internal Spread (Design Scenario)
**RC** Robustness Check (Design Scenario)
**SF** Smouldering Fire (Design Scenario)
**SS** Structural Stability (Design Scenario)
**UF** Unexpected catastrophic Failure (Design Scenario)
**UT** Unoccupied Threat (Design Scenario)
**VS** Vertical fire Spread (Design Scenario)

***Table 4: FSVM Occupant Response and Movement Considerations for each Design Scenario***

[15] PEEPS is adopted. An example in a 19 storey office building in Manchester of an occupant confined to a manual wheelchair with a high level of upper body "core" strength managed his own evacuation and was committed to it by signing off on his own PEEPS. During the observed evacuation forming part of the international case study on stair descent in trial evacuations (MacLennan, 2013)[12]the above occupant descended the stairs on his "hands" whilst the colleague carried the chair. The MWC occupant did not hold up other participants and this was practised at least every 6 months. The PD7974-6 quality of fire safety management was M1.

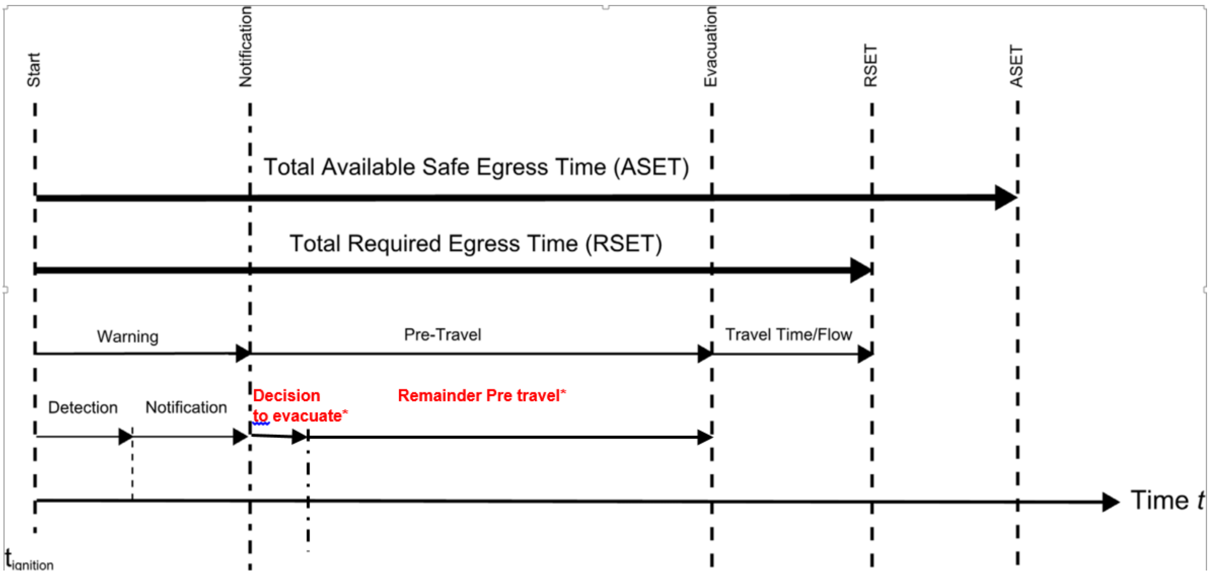
Overall occupant capabilities are therefore a function of the limitations identified in *Figure 2* above. Although the Washington Group based approach is recommended to determine the occupant Type it may be incomplete where there are co-morbidity issues, as is the case with morbidly obese occupants and those over the age of 65 years that have not been taken into account. EBEP's submission to ABCB on DV2 in Appendix A.

In conclusion the Design Occupant is really the Occupant Type as defined in Tables 10 and 11 of the FSVM. As such the implied occupant characterisation model used to derive the Design Occupant is incomplete in terms of the context of the performance clauses as summarised in **Table 1** above. EBEP recommends an inclusive based model centred on capability[16] as presented and refined in Section A5 of their DV2 Stage One Submission to ABCB. This task could be completed as part of the Stage 2 ATM. ***Table 4*** could be redrafted in this exercise. It still does not overcome the conundrum discussed in Section 3.3 of this submission.

## 3.5 Defining RSET

### 3.5.1 The Framework

The ASET/RSET framework forming the basis of the FSVM is shown below in **Figure 3** below.




* Currently suggested in FSVM Section 5.6.3 to add 20-40s to detection for notification time. It is the occupant response to the notification which is in question as it depends on the quality of the quality of the alarm (see PD7974-6) Remainder pre-travel time will depend on familiarity with and practising the procedures especially with the 9/11 case study example. This underpins the estimation of pre-travel times in FSVM Table 14.

***Figure 3: Revisiting RSET***

The framework shown in **Figure 3** will be discussed under the following headings;

1. Warning (3.5.2)
2. Pre-travel (3.5.3)
3. Movement

Before going any further Section 5 of the FSVM claims that the incipient stage time can be viewed as a RSET safety factor. The example shown in **Figure 4** below indicates that this

[16] Adapted from Matheson, L. (2003). *The functional capacity evaluation*. In G. Andersson & S. Demeter & G. Smith (Eds.), Disability Evaluation. 2nd Edition. Chicago, IL: Mosby Yearbook.

assumption may far too optimistic. The time to ignition which is when fire growth commences, can vary from "0" upwards. This assumption should be removed as it could be misleading.

The reliability of the calculation method[17] used for each of the RSET components varies as follows;

1. **Warning**: Quality of warning device in terms of occupant response capability.
2. **Pre-travel**: Occupant status, characteristics and familiarity with what to do.
3. **Movement**: Occupant mobility and wayfinding ability (see Figure 5 below)

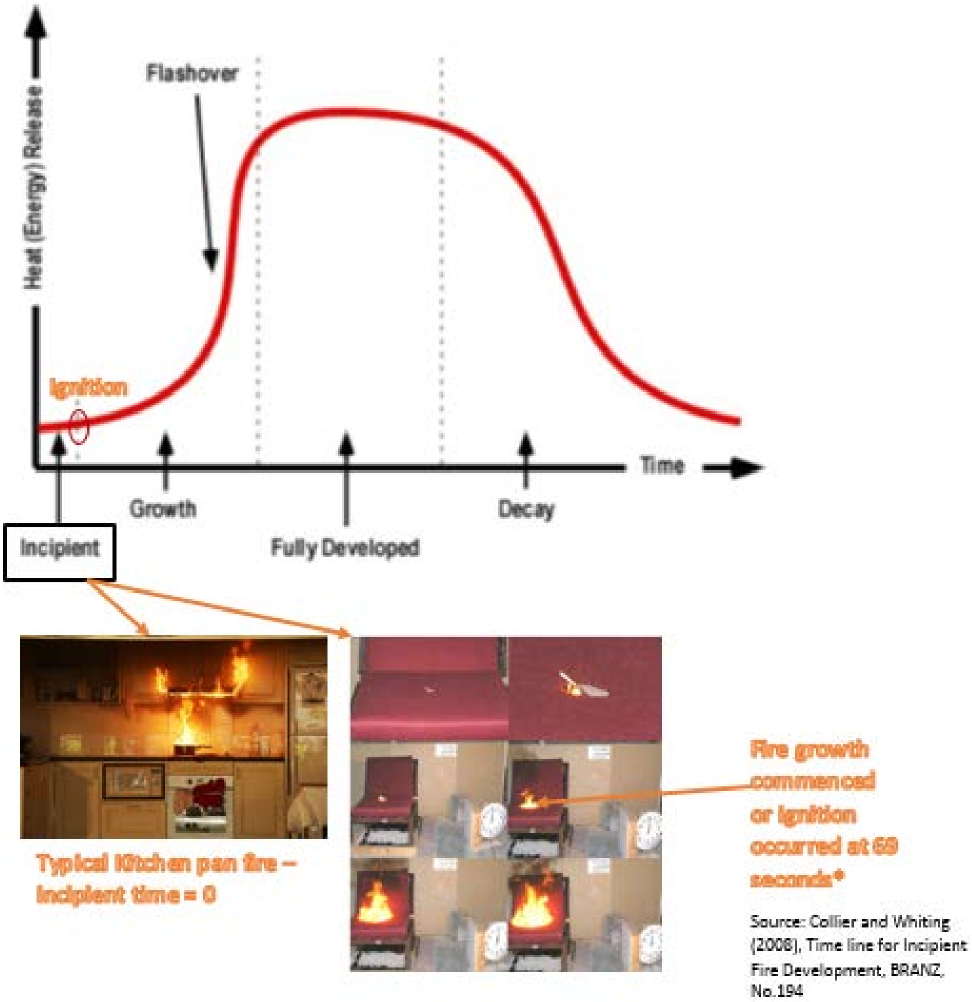



***Figure 4: Incipient stage a RSET safety factor?***
*Note: 40.6% of fires start in kitchen and 21.9% in bedroom for Class 1 buildings[18] and this risk would be similar for a Class 2 Sole Occupancy Unit.*

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[17] These comments are made especially in the light that the elements form part of the "Simplified"
[18] Australian Fire and Emergency Service Authorities Council (2009) *Accidental Fire Injuries in Residential Structures: Who is at Risk*? AFAC Section 9.

### 3.5.2 Warning

Warning in the FSVM comprises detection time and time for communicating a warning to the occupants. The time for these components is generally evidence based by test or experiment. What is missing is the anticipated occupant response and decision outcome. A positive decision depends on;

- Media of communication – matching with needs of the occupant (audio, visual and/or tactile (vibrating) and occupant functional limitations)
- Quality of information and familiarity of occupant of how to respond
- Status of occupant at time of warning (asleep or awake; cognitive ability to respond; location of occupant; under medication for depression or similar; consumed alcohol or drugs; dementia; etc.)

It is here that the Washington Group Model is extremely useful because as demonstrated in Appendix A5 of the EBEP Submission to the ABCB via a functional capacity model which if used correctly increases the reliability of the design occupant data. This model relies on evidence based input so that in a situation where the occupant is asleep, a child or older person, and other impairments the alarm system could be designed based on tests such as that of Bruck and Thomas (2008)[14] for audio and/or tactile alarms. PD7974-6 refers to this in that there is a rating scale for alarm types. Merely allowing a notification time of 20-40s at the end of which it is assumed that the occupant is alert enough to respond is not recommended. It needs to be evidence based as has been the case with sleep studies such as as that conducted by Bruck and Thomas (2008)[14]. Proulx (2000)[19] advises that the notification message should contain three important pieces of information;

- Identification of the problem
- Location of the problem
- Instructions for action

She confirms also that the probability of an immediate response will increase with prior training and a simple practised evacuation plan[19]. This is also confirmed by Robbins and Warren (2015)**[Error! Bookmark not defined.]**. The message must be the truth and be simple. Also the design must be evidence-based. The current approach is not acceptable even with the justification of the extra time available from the incipient stage of a fire as illustrated and described in **Figure 4** above (0-69+ seconds).

### 3.5.3 Pre-travel Time

It is suggested that pre-travel time comprises two components especially when the most important is the "decision to evacuate". The reader should refer to the 9/11 case study of the WC occupant and her speed of response being a function of her training and company commitment to OH&S. There is further evidence in the longitudinal case study of class 5 building trial evacuations where simple and practised trial evacuations were reflected in faster evacuation times[12]. Most of the time saved was that associated with "pre-travel". Another reason was the reliability of the instructions given out with the notification of the alarm and their clarity.

**Table 5** is an analysis of Table 14 in the FSVM and includes a comparison with Table 3.3 in the NZ C/VM2 documents. In general terms it does not reflect the results of research or the informed suggestions in Table C.1 in PD7974-6. The times depend on the reliability of the information and instructions given under the Warning phase. There are many reasons why

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[19] Proulx G, (2000) *Strategies for Ensuring Appropriate Occupant Response to Fire Alarm Signals*, IRC-CNRC, Construction Technology Update 43.

occupants may not respond or make a decision to commence evacuation which has been extensively researched (Proulx, 2000; MacLennan, 2013; Robbins and Warren, 2015; etc.). Pre-travel times could vary by some 300% as evidenced in the Retail Studies

The evacuation capability of occupants is also a limiting factor in that many would not be able to make a decision to evacuate or even to prepare for evacuation without assistance. This could amount to 20% of the population taking into account children, older persons, larger persons, status of occupant (drugs/ medication). All occupancies therefore need a fire safety and management plan. Where the plan has been implemented, the strategy kept simple and regularly practised the pretravel time can be kept to a minimum in that it is a delay.

All of the above has been recognised by the experts who developed PD7974-6 and is summarised in Table C.1 of that document.

See **Table 5** below for comments on Table 14 of the FSVM.

*Table 5: Pre-travel Times Comparison of FSVM with NZ C/VM2*

| ***Description of building use*** | ***Enclosure*** | ***Pre-travel activity time(s)*** |
|---|---|---|
| Buildings where the occupants are awake, alert and familiar with the building (e.g. offices, warehouses not open to the public) | Enclosure of origin | 30<br>Not evidence based & do not reflect PD7974-6 |
| Buildings where the occupants are awake, alert and familiar with the building (e.g. offices, warehouses not open to the public) | Remote from the enclosure of origin | 60<br>Depends on trial evacuation practice and simple procedure |
| Buildings where the occupants are awake, alert and unfamiliar with the building (e.g. retail shops, exhibition spaces, restaurants) | Enclosure of origin (standard alarm signal) | 60<br>Depends on fire safety/ evacuation management. Complex procedures would extend this time |
| Buildings where the occupants are awake, alert and unfamiliar with the building (e.g. retail shops, exhibition spaces, restaurants) | Remote from the enclosure of origin (standard alarm signal) | 120<br>As above |
| Buildings where the occupants are awake, alert and unfamiliar with the building (e.g. retail shops, exhibition spaces, restaurants) | Enclosure of origin (voice alarm signal) | 30<br>Not evidence based as lack of organisation and information could result in mistaken instructions |
| Buildings where the occupants are awake, alert and unfamiliar with the building (e.g. retail shops, exhibition spaces, restaurants) | Remote from the enclosure of origin (voice alarm signal) | 60<br>As above |

| | | |
|---|---|---|
| Buildings where the occupants are sleeping and familiar with the building (e.g. apartments) | Enclosure of origin (standard alarm signal)<br>Not supported by research | 60<br>Not evidence based. Some occupants such as older persons and children may not respond at all. |
| Buildings where the occupants are sleeping and familiar with the building (e.g. apartments) | Remote from the enclosure of origin (standard alarm signal)<br>Depends on clarity and reliability of instructions given with warning and status of evacuation management | 300<br>Not evidence based. A two staged alarm system is often extremely confusing. Time may be >300s |
| Buildings where the occupants are sleeping and unfamiliar with the building (e.g. hotels and motels) | Enclosure of origin (standard alarm signal)<br>900s for Type C | 60<br>See apartments. |
| Buildings where the occupants are sleeping and unfamiliar with the building (e.g. hotels and motels) | Remote from the enclosure of origin (standard alarm signal)<br>900s for Type C | 600<br>Would depend on the quality of the evacuation procedures and their management |
| Buildings where the occupants are sleeping and unfamiliar with the building (e.g. hotels and motels) | Remote from the enclosure of origin (voice alarm signal) | 300<br>Not evidence based as shown by Bruck and Thomas (2008) in terms of waking up. Could be >300s |
| Buildings where the occupants are awake and under the care of trained staff (e.g. day care, dental office, clinic) | Enclosure of origin (independent of alarm signal) | 60<br>Not evidence based but realistic but would depend on the skill of the staff and size of the room. |
| Buildings where the occupants are awake and under the care of trained staff (e.g. day care, dental office, clinic) | Remote from the enclosure of origin (independent of alarm signal) | 120<br>As above |
| Buildings where the occupants are sleeping and under the care of trained staff (e.g. hospitals and rest homes) | Enclosure of origin (assume staff will respond to room of origin first)<br>Should refer directly to available databases e.g. Exodus | 60 s for staff to respond to alarm then 120 s (per patient per 2 staff)<br>Also depends on skill of staff and whether they practise regularly |
| Buildings where the occupants are sleeping and under the care of trained staff (e.g. hospitals and rest homes) | Remote from the enclosure of origin (independent of alarm signal)<br>Should refer directly to available databases e.g. Exodus | 1800<br>This is really “staged evacuation” and is only as good as the fire/smoke management systems as well as emergency management practices |

| | | |
|---|---|---|
| Buildings where the occupants are sleeping and under the care of trained staff (e.g. hospitals and rest homes) | Remote from the enclosure of origin (independent of alarm signal) where occupants are unable to be moved due to the procedure or other factor | 1800 or as per specific requirements, whichever is the greater.<br><br>See above |
| Spaces within buildings which have only focused activities (e.g. cinemas, theatres and stadiums) | Space of origin (occupants assumed to start evacuation travel immediately after detection and notification time or when fire in their space reaches 500 kW, whichever occurs first) | 0<br><br>Does not make sense. Wardens have to gain and access and take up positions. Fire scenarios vary to a great degree so that there needs to be a range of times |

**** Indicates complete agreement between the tables. Consult also Table C.1 of PD7974.6 to see impact of behavioural factors and scenarios.***

The FSVM indirectly adopts the Washington Group approach to occupant characterisation as evidenced in Tables 10 and 11 is reflected in Table 12 where the pre-travel time is adjusted. This adjustment is based on the 99th percentile as quoted in PD7974-6. It may still be inadequate for occupants with dementia and other conditions which impair response and decision making[20].

***Table 6: Table 12 from FSVM for Type C Occupants***

| ***Characteristic*** | ***Mobility*** | ***Hearing*** | ***Vision*** |
|---|---|---|---|
| Vertical travel speed using stair (m/s) | 0 | Refer to Section 5.6. | 0.71 |
| Horizontal travel speed (m/s) | 0.69 | 1.2 | 0.86 |
| Occupant density | Stationary: 0.8925m2 (1216 x 813mm)7<br><br>180 degree turn: 3.18m2 (1540mm x 2070mm) | Refer to Section 5.6. | Refer to Section 5.6. |
| Notification time (recognition) | Refer to Section 5.6. | Appropriate to available cue. Refer Section 5.6. | Refer to Section 5.6. |

[20] See Robbins and Warren (2015)**Error! Bookmark not defined.**, Spearpoint and MacLennan (2012)[9], Miller and Davey (2007), *The risks, perceptions and experiences of fires among older people*, Heimdell Consulting, and confirmed in statistics on mental health counting for 22% of the population in NSW (McCausland et al, 2013, People with mental health disorders and cognitive impairment……). See also Xiong, Bruck and Hall (2016) DOI10.1002/fam2356.

| | | | |
|---|---|---|---|
| Pre-travel time (subject to 5.6.4) | 900 s* (when sleeping and unfamiliar)8<br><br>Otherwise, as per Section 5.6 | Assume occupant is remote from compartment of origin. Refer 5.6.4. | 900 s* (when sleeping and unfamiliar)<br><br>Otherwise, as per Section 5.6 |

### 3.5.4 Movement times and ability

Refer to ***Figure 2*** where factors affecting mobility are clearly noted. This should be read in conjunction with the work of Spearpoint and MacLennan (2012)[9] and Robbins and Warren (2015)**Error! Bookmark not defined.** along with similar works where "public health" data on movement ability (speeds) such as Stringhini et al (2018)[21]. These data illustrate the possibility that the FSVM data in Table 15 is somewhat optimistic especially for the Type C Occupants reflected in **Table 6** as 0.69m/s. This is confirmed by MacLennan (2013) for morbidly obese occupants (BMI and waist girth measurements) in **Table 7** and highlighted yellow, and also for older persons in **Table 9**. When these speeds are compared with the FSVM speeds in **Table 8** we can conclude that the allowance is extremely optimistic.

*Table 7: MacLennan (2013) Comparison of Stair Descent Speeds with Seminal Movement Studies[12]*

| *Reference* | *Descent Speeds* | | | *Comments* |
|---|---|---|---|---|
| | *Mean* | *Max* | *Min* | |
| *Peacock, Kuligowski & Averill (2009)* | *0.83* | *1.01* | *0.65* | *6 storeys* |
| *Peacock, Kuligowski & Averill (2009)* | *0.73* | *0.99* | *0.47* | *6 storeys* |
| *Peacock, Kuligowski & Averill (2009)* | *0.62* | *0.72* | *0.52* | *11 storeys* |
| *Peacock, Kuligowski & Averill (2009)* | *0.4* | *0.49* | *0.31* | *18 storeys* |
| *Peacock, Kuligowski & Averill (2009)* | *0.54* | *0.72* | *0.36* | *18 storeys* |
| *Boyce et al (1999)* | *0.7* | *1.1* | *0.45* | *Visually impaired person - 0.31m/sec* |
| *MacLennan (2012)* | *0.9* | *1.8* | *0.6* | *Younger Office Workers - 22-34yrs comprising male and female* |
| *MacLennan (2012)* | *1.01* | *1.4* | *0.77* | *Younger Office Workers - 22-34yrs comprising male and female* |
| *Fahy and Proulx (2001)* | *0.47* | *1.08* | *0.31* | *Mid-rise apartment* |
| *Fahy and Proulx (2001)* | *0.44* | *0.56* | *0.32* | *Mid-rise apartment* |
| *Fahy and Proulx (2001)* | *0.41* | *0.47* | *0.3* | *Mid-rise apartment* |
| *Proulx et al (2007)* | *0.4* | *1.03* | *0.17* | *Slow mean speed caused by two morbidly obese persons – 13 storey office building* |
| *Boyce et al (1999)* | *0.33* | *0.7* | *0.11* | *Allowing for persons with locomotion disability* |
| *Boyce et al (1999)* | *0.13* | *0.23* | *0.11* | *Assisted group of people with impaired vision* |
| *MacLennan (2012)* | *0.36* | *0.42* | *0.29* | *Includes BMI >35 and Waist measurement >1000mm* |
| *MacLennan (2012)* | *0.33* | *0.36* | *0.28* | *Includes BMI >35 and Waist measurement >1000mm* |
| *Jiang et al (2012) -* | *1.14* | *1.427* | *0.859* | *mobile young* |
| *Jiang et al (2012) -* | *0.85* | *1.038* | *0.662* | *disturbed gait but no aid* |
| *Jiang et al (2012) -* | *0.433* | *0.571* | *0.295* | *single crutch* |
| *Jiang et al (2012) -* | *0.332* | *0.463* | *0.201* | *two crutches* |

The mean travel speed in **Table 7** above for office workers less than 40 yrs. is 0.9m/s with a minimum of 0.6m/s. Morbid obesity (representing a ICF classification) for a significant

[21] Stringhini et al (2018), Socioeconomic status. Non-communicable disease risk factors, and walking speed in older adults…….., *BMJ*, doi:10.1136/bmjk1046

section of the population reduces this to 0.36m/s (250%). This should be reflected in the FSVM given the findings of Spearpoint and MacLennan (2012)[9].

*Table 8: FSVM Table 15*

| Exit route elements | Exit route elements | k | Speed (m/s*) |
|---|---|---|---|
| Corridor, aisle, ramp, doorway - stair riser (mm) | Corridor, aisle, ramp, doorway - stair tread (mm) | 1.40 | 1.19 |
| 191 | 254 | 1.00 | 0.85 / <0.69 Type C occupant |
| 178 | 279 | 1.08 | 0.95 |
| 165 | 305 | 1.16 | 1.00 |
| 165 | 330 | 1.23 | 1.05 |

*Table 9: Horizontal Travel speeds – Systematic Review (Health Science) by Peel et al[22]*

| Pace | Location | Gait speed estimates (m/s) | 95% CI |
|---|---|---|---|
| Usual | Acute | 0.45 | 0.344-0.567 |
| | Sub-acute | 0.529 | 0.438-0.619 |
| | Ambulatory | 0.739 | 0.648-0.831 |
| Maximal | Acute | 0.749 | 0.592-0.905 |
| | Sub-acute | 0.822 | 0.711-0.933 |
| | Ambulatory | 1.033 | 0.910-1.156 |

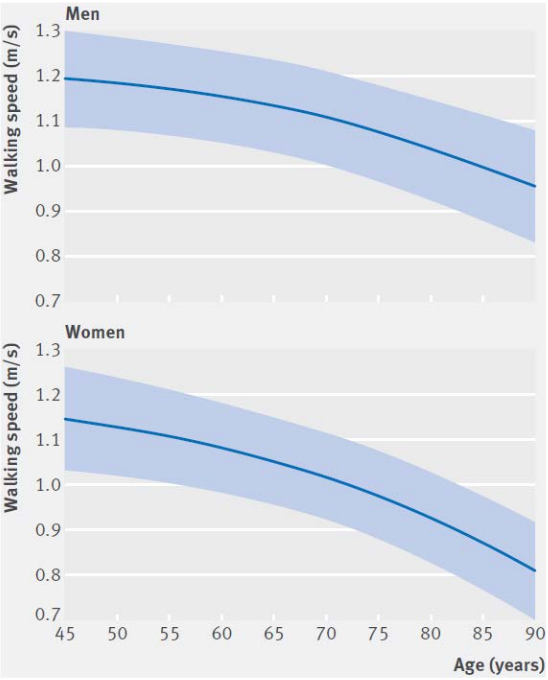


*Figure 5: Impact of Age on Horizontal Walking Speed[21]*

The impact of age is less marked as explained by **Figure 5**[21] but challenged by a systematic review study by Peel et al (2012)[22] of the same age groupings as shown in **Table 9** where

[22] Peel NM, Kuys SS, and Klein K, (2012) Gait speed as a measure of Geriatric Assessment in Clinical Settings, Medical Science, Vol.68, No.1, pp. 39-46.

the mean gait speed is some 0.45m/s. MacLennan (2013)[12] also confirmed that the morbidly obese occupants had issues with their dynamic stability on stairs as did Type B vision impaired occupants due to depth perception and increase in age due to a cognitive impairment known as the "fear of falling". All these relationships discussed above were found to be statistically significant at $p<.05$. Further confirmation may be found in the exhaustive review by Robbins and Warren (2015). The importance of these data is that the variation can be explained whereas the source of the range in speeds in FSVM Table 15 cannot. There are data bases that can be referred to for the Simplified Method e.g. Robbins and Warren (2015)**Error! Bookmark not defined.** and Spearpoint and MacLennan (2012)[9]. Perhaps the entire issue of Mobility can be explained by the mobility functional limitation model in **Figure 6** below

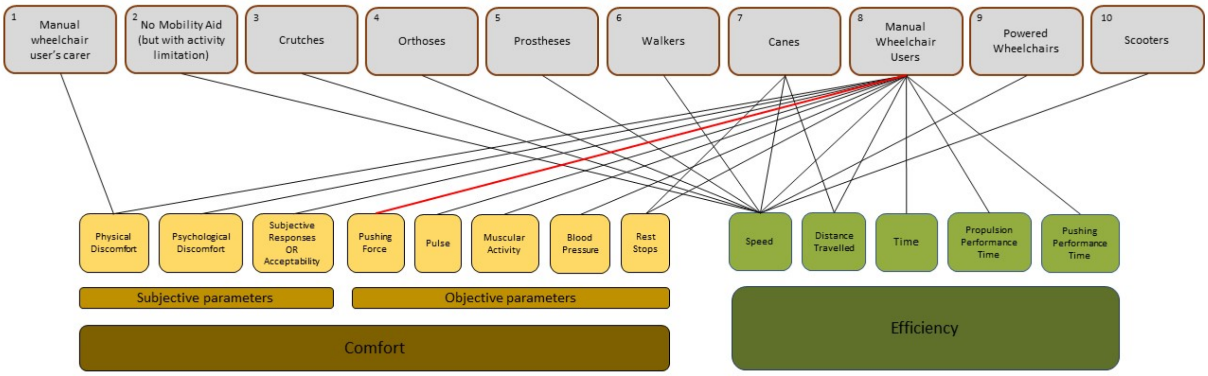


*Figure 6: Mobility Limitation Model (ABCB DV2 Report submitted by EBEP-UNSW)*

## Occupant Movement Challenges – Characterised by requiring use of assistive device:

Gaire et al (2018)[23] is a study of exit choice in the real world (case study). A comparison is made between occupants with and without disabilities. It demonstrates significant differences in choice between the two groups. This raises the conundrum of Section 5 of the FSVM. Reference is made to the discussion in Section 2 of this submission, being the introduction. Using the study of Robbins and Warren (2015) highlighted in section 2 of this submission and the intent of DP7 the performance objectives of DP4 can be answered with respect to suitable exit types;

- Provide conventional exits coupled with PEEPS for all those occupants using assistive mobility devices – possible outcome of using evacuation chair in line with 9/11 case study evacuation strategy and practice.
- Provide combined stair and evacuation lift compliant with arrangements shown in **Figure 7 and Figure 8** (ABCB Handbook). Sizing in accordance with evidence-based study by Heyes and Spearpoint (2009)[24]

[23] Gaire et al, (2018) *Exit Choice Behavior of Pedestrians Involving Individuals with Disabilities During Building Evacuations*, Transportation Research Record, DOI: 10.177/0361198118756875.

[24] Heyes E and Spearpoint M, (2009) *Lifts for evacuation – Human behaviour considerations*, Proceedings of 4th International Conference on Human Behaviour in Fire, 13-15 July 2009, Cambridge, UK, pp. 73-84. Also available in University of Canterbury Report, Master of Fire Engineering Programme.

- Provide other suitable evidence-based solution which is familiar to occupants and/or emergency-management team. All solutions should be fully accessible where refuge type proposals are to be considered.

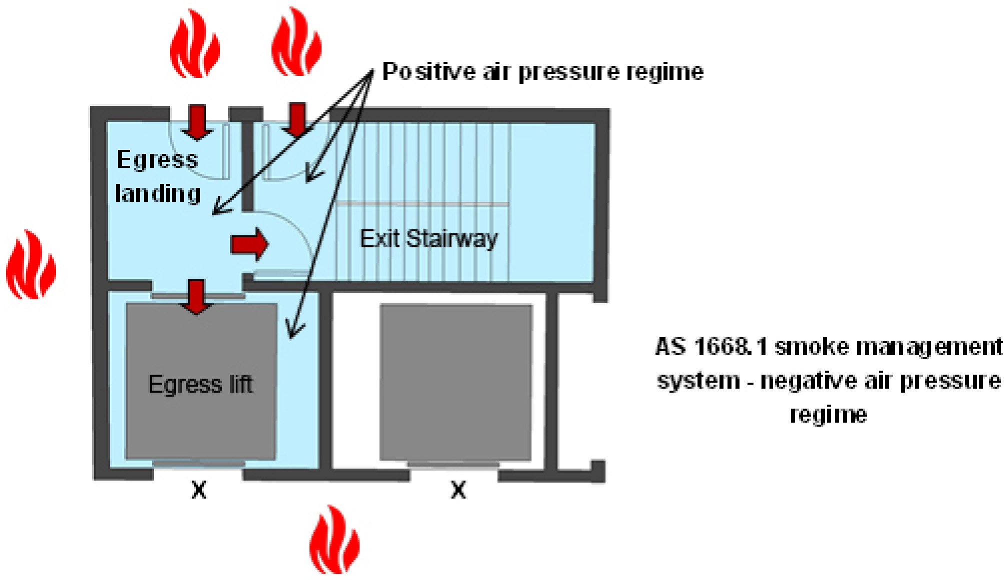


*Figure 7: Reproduction of Figure 7.3 from ABCB Handbook – Lack of Occupant Familiarity*

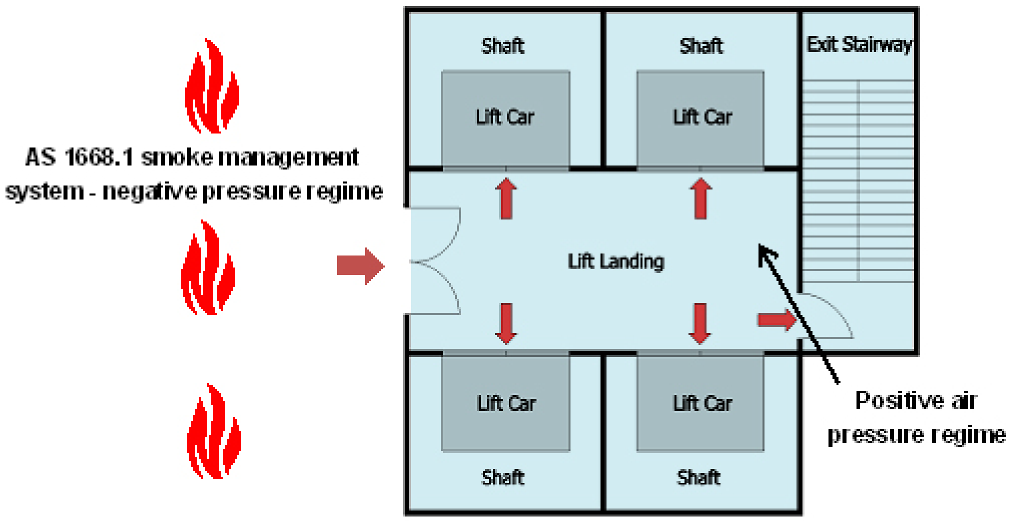


*Figure 8: Reproduction of Figure 7.2 from ABCB Handbook – Occupants have increased chance of being familiar with this layout because of access requirements and practice*

The current wording of DP7 does not provide any incentive for performance design in that provision of evacuation lifts does not provide any further opportunities for the rationalisation of exits. The ABCB Evacuation Handbook does detail a performance alternative for DP7 and when linked with engineering calculation models similar to that proposed by MacLennan et al

(2008)[25] based on a lift selection model known as Elevate by Peters[26] allows for the development of a cost-effective. In order for the egressibility of a building to be reliable the systems of access and egress need to be completely integrated as inferred by Gaire[23].

The use of personal emergency evacuation plans (PEEPS) which are already catered for in AS3745 needs to be underpinned by a fully developed set of emergency evacuation procedures that are simple and have been practiced so that there is no occupant confusion as a result of possible conflicting instructions via the warning system[27]. If this is the case then the allocation of queuing space at exits can make adequate provision for the needs of the mobility impaired so as they are not intimidated by the lack of space for manoeuvring associated with normal exit access. The exit arrangement shown in **Figure 7** could be easily adapted to be provided with a lobby that could accommodate the occupants who are prepared to use lifts in an evacuation. This information would be available from PEEPS records available to the emergency management team in the building concerned. The number used initially in development of the design solution could be based on 3% of the floor population with the space suitable for 3 wheelchairs with the A-90 footprint. The other alternative would be a circulation simulation of lift and stair access to establish the space requirements with the general arrangement of lifts and fire stair shown in **Figure 8**.

Use can be made of PEEPS as part of the performance solution, although many would see it as an emergency management tool, because of the mechanisms available in each State to ensure ongoing compliance[28]. This approach is used in Access as advised in the EBEP Submission on DV2 Access to and around Buildings to the ABCB.

## Delayed Evacuation

**Delayed evacuation** is also known as;

- Staged evacuation
- Sequential evacuation
- Defend in place.

This type of evacuation strategy is often associated with apartment complexes, large retail facilities, cinemas, hotels and other public buildings where the building concerned is divided into compartments. Horizontal egress may be associated with it. When this type of strategy is envisaged then there needs to be smoke control and fire control systems that will prevent the spread of fire in such a manner as to allow the Fire Brigade and Rescue Service to take control of the incident and to evacuate the remainder of the building as required. Delayed egress coupled with horizontal egress forms an integral part of hospital design as occupant “patients” may be totally incapacitated and require assistance.

**Delayed evacuation** is quite common in multi-storey buildings and is associated with a staged warning system comprising;

- Alert tone – making people aware
- Associate Voice Message – instructions (need to be simple, truthful, and reliable to avoid confusion

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[25] MacLennan H, Ormerod M, Sivan A, Nielsen C, (2008), Will current high rise evacuation systems meet user needs in 2030, *Elevcon* 2008, Thessaloniki, pp. 257-267.

[26] Fully described and cited in footnote 26 above.

[27] Proulx G, Reid I, and Cavan N, (2004) *Human behaviour study – Cook County Administration Building Fire October 17 2003 Chicago Illinois*, Research Report No. 181, National Research Council Canada, Ottawa.

[28] E.g. Fire Safety Act and Regulations Queensland and Critical Fire Safety Measures Mechanism in NSW,

- Evacuate tone
- Associated Voice Message.

The length of delay between messages or the pattern of messages can create confusion where they do not match what is happening on the ground or the length of the interval between each announcement or signal can result in uncertainty and create stress amongst the occupants[27]. There are some instances where occupants may start taking matters into their own hands. Hopefully the attending Fire Brigade will eventually bring things under control.

As stated under 3.5.2 of this submission often complex warning regimes can extend evacuation times making up RSET by an alarming amount. The Australian Standard associated with emergency management and evacuations is AS3745. Informed compliance and training together with a simple and practised organisation and procedure will result in smoother evacuations where participants are ever familiar with "what to do". This then underpins **delayed evacuation** planning and RSET design.

# 4. Recommendations and Conclusions

## 4.1 Conclusions

The FSVM as written is an extremely good start. The wording of the associated performance clauses create a conundrum in terms of the associated DtS framework which does not incorporate provisions for those occupants with disabilities (DP2, DP4-DP6). Occupant characteristics are quite specific as explained in this Submission that disability should be included e.g. Occupant Type C. The DV2 Proposal on performance based Access also refers to the same clauses as well as to DP1. There is common ground in Occupant Characterisation so that a common method needs to be developed.

The way forward needs to reflect the minimum provision which usually resides in a DtS solution. If the latter makes no provision for Access then the performance clauses relating to egress need to be modified in terms of occupant characteristics and level of mobility. If this action is not implemented then we have to conclude in the strongest way that the conundrum continues.

## 4.2 Recommendations

EBEP make the following recommendations:

1. Re-evaluate the DtS provisions of D1 and D2 of the NCC in as far as Building Egressibility is concerned for disabled occupants, children and older persons as these groups account for approximately 30% of the population. There are marked issues with Type B and C Occupants.
2. If the DtS provisions are to remain then revisit the objectives of all the performance clauses nominated in ***Table 4*** of this Submission.
3. Take into account the links between DV2 and Egress reflected in Table 1 of this submission and the need for the development of a common occupant characterisation method for the FSVM and DV2. Incorporate as part of the completion of DV2 stage 2.
4. Strongly consider the inclusion or adoption of soft design aids such as emergency management procedures, PEEPS and assistive evacuation movement aids given the number of evidence-based studies that have been carried out and also the management in use control tools available via AS 3745 and State Legislation / Essential Services Regulations.

5. Adopt the recommendations of Robbins and Warren (2015)[2] given the evidence based case study of the 9/11 Incident[5].
6. Revisit the Occupant Characterisation Model and develop to complement DV2 utilising the value of the Washington Group Approach for which there is ABS Data available. Occupant capability can be transparently established.
7. Revisit RSET provisions and compare with PD7479-6 as suggested viz;
    a. Consider developing a FSVM flow chart on the same basis as NZ C/VM2
    b. Safety Factor – Remove the advice re the use of the Incipient Spread of Fire time as a safety factor in the estimation of pre-travel time.
    c. Warning – undertake a rigorous review of warning messages (see 3.5.2) and the implied or practised evacuation procedure and the use of PEEPS to underpin the simplicity and reliability of the building emergency evacuation system. Also review the occupant status and familiarity with the warning signal to determine the risk of non-response.
    d. Pre-travel – undertake a rigorous review of the FSVM following the suggestions outlined in Table 5 in that it does not reflect the results of evidence-based research and also Table C.1 in PD7974-6. This time must also relate to occupant characteristics and needs to include older persons and children. Pre-travel time relies heavily on familiarity with "what to do" when they hear an alarm. Times need to be adjusted accordingly and the value of management and practice accepted as advised.
    e. Movement – review the following;
        i. Movement times; revise to accurately reflect occupant characteristics, status and evacuation familiarity as presented in the findings of Robbins and Warren (2015)[2] and evidence based data shown in Tables 7, 9 and Figure 5. Take into account implications of the Mobility Limitation Model as shown in Figure 6 and presented in the EBEP DV2 Submission to ABCB. Revise speeds in line with this recommendation
        ii. Show how PEEPS can cut evacuation times (a and b) by some 300% as measured in practice (MacLennan, 2013[13] and Proulx et al, 2004[28]) and incorporate in FSVM
        iii. Exit type and choice: Consider the use of PEEPS and the revision of DP7 to provide an incentive for designers to add value, offer innovative solutions improving the egressibility of the building, incorporate inclusive exit choices ranging from assistive devices to built-in exits such as shown in Figures 7 and 8 matched with simple design tools relating to occupant capacity.
        iv. Delayed evacuation - only permit if managed and in line with AS3745 and where interfacing with other fire safety systems is kept to a minimum.
8. Link across transparently between the FSVM and DV2 and consider as part of DV2 Stage 2 Submission.