A STUDY OF THE PERFORMANCE OF OFFICE WORKERS DESCENDING MULTIPLE FLIGHTS OF STAIRS IN HIGH RISE OFFICE BUILDINGS IN TRIAL EVACUATIONS

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A STUDY OF THE PERFORMANCE OF OFFICE WORKERS DESCENDING MULTIPLE FLIGHTS OF STAIRS IN HIGH RISE OFFICE BUILDINGS IN TRIAL EVACUATIONS

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Volume I of II

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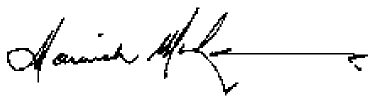
Declaration

This is to certify that the copy of my thesis which I have submitted for consideration for my post graduate degree:

- Embodies the results of my own course of study and research
- Has been composed by myself
- Has been seen by my supervisor before presentation

Signature of candidate/ author



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Abstract

Aim:

The Aim of this PhD study is to study the performance of mature age office workers descending multiple flights of stairs in trial evacuations of high rise office buildings in the context of extrinsic and intrinsic factors.

Method:

A case study process coupled with mixed methods data collection and analysis was selected with the unit of analysis being the office worker descending the stairs. An Exploratory case study involving the reanalysis of data from a similar study[1] was undertaken to confirm the selection of the research method.

Six high rise buildings were selected varying from 7 to 36 storeys[2]. Trial evacuations were held and data collected via survey, observation and physical assessment. Two explanatory case studies involving a Delphi group and focus groups classified the main contextual issues as the intrinsic ones of the occupant and the extrinsic ones of Stair Design and Construction, Others on the Stairs and Management/ Maintenance. The other explanatory study comprised a directed content analysis of a two extremely relevant media documents[3] related to multiple flight stair descent. The data was analysed and findings established by generalisation where trends could be explained quantitatively and otherwise via triangulation.

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[1] A similar study was undertaken during the 1980's of trial evacuations from 8 high rise buildings where the data collection comprised mixed methods.

[2] The basis of selection was defined by the Exploratory case study experience except that the maximum height decreased from 45 to 36 storeys. The range of heights was similar (average of 24-25 storeys). The case study is known as the 2008-2010 case study.

[3] WTC 9/11 incident survivor study by Dwyer and Flynn of the New York Times (2004) and a NY times facilitated Blog concerning community attitude to fitness and surviving an emergency.

Results and Conclusions:

Fatigue predicting descent performance ability was determined by triangulation and generalisation. Density could mask fatigue as the result of delays that would allow people to descend at more slowly. Descent performance ability for 50% of the population was 300 metres in 1980 reducing to 240 metres in 2010. The risk of falling related directly to this distance and the spiralling action of turning at each landing[4]. Triangulation showed this action increased the risk of vertigo and dizziness as well as the impact of increased BMI and health conditions on stability. The significant ($p<.05$) contextual extrinsic factors were found to be stair descent risk, need for clear visibility and support from reachable handrails, trial evacuation strategies and procedures and group dynamics. There are other less significant findings[5] explained by context and the "cause and effect directed"[6] case study research method.

[4] 3-14% of the building population which was confirmed via triangulation.

[5] e.g. Occupants view of steps obstructed by others in the group, actual and estimated performance correlated highly with fatigue ($R^2 > 0.5$, $p<.05$), See also Chapter 8.

[6] Utilising the Ishikawa Chart as part of a process known as Root Cause Analysis (Portwood and Reising, 2007)

Chapter 1: The Research Problem, Questions, Aim and Objectives

1.1 Introduction

High Rise Office Buildings have and will continue to increase in height since studies confirm that the principle of high density commercial development is economically sustainable (Buchanan and Partners, 2008). As these buildings increase in height[7] the risk to the occupants increases as they may have to go down a greater number of stairs to get to ground level in event of an emergency (Bukowski, 2009). Going down stairs is one of the most dangerous tasks that a worker in a high rise office building may have to undertake especially as they grow older (Reeves et al, 2008). Al-Abdulwahab (1999) shows that individuals older than 40 years start to lose their strength and develop other problems associated with a sedentary lifestyle. In the UK, for example, over 50% of office workers will be 40+ years of age over the next ten years (Dixon, 2003). The physical task of going down an increased number of stairs may be too much and the challenge is whether the individual is fit enough and strong enough to accomplish this task (Parker-Pope, 2008).

1.2 The Research Problem

1.2.1 Buildings increasing in height – does this require greater effort?

As office buildings increase in height so does the distance that the individual is required to go down the 'fire stairs' increase. The trend of new office building is to generally be of increasing height (Bukowksi, 2005 and Buchanan and Partners, 2008) so that the required physical effort, level of fitness

[7] Ranging from buildings such as One Chase Manhattan Plaza constructed in 1961 with a height of 248m to 509m high for Taipei 101 in Taiwan in 2004 and Burj Khalifa in Dubai of 828m. All these buildings were constructed under USA Codes. Bukowski (2005) provides further examples.

and functional ability of office workers needs to increase. Studies of the WTC 9/11 incident did not really support this opinion in terms of the measure of fatigue (Galea et al, 2008a) and also functional limitations (McConnell et al, 2010) most likely due to the reduction of descent speed because the stairs were crowded offering people the chance to rest. Galea et al (2008) did also comment that the number of delays experienced whilst descending the stairs may have also allowed the individuals to rest.

1.2.2 Emergency preparedness and health and safety – evacuation drills?

The WTC 9/11 incident did raise the need for an improvement in knowing what to do in event of an emergency and also doing it in the minimum amount of time, especially when the requirement is to evacuate the building (Averill et al, 2005). Health and Safety Law in most countries such as the UK, Australia, New Zealand and the United States[8] now mirror this requirement so that building owners and employers are required to organise evacuation drills that replicate an emergency incident so that office workers can practice what they have to do and be familiar with the exit routes and the overall evacuation plan. Trial evacuations may not always reflect the same findings as those of Galea et al (2008 and 2008a). There may be the case when the evacuation plan is such that the timing of the entry of individuals and their colleagues into the stairs results in there being less people in the stair at any one time (Pauls 1977)[9]. Other studies show that people can move at their own speed or that of the group when their path is not blocked by others (Templer, 1992, Nelson and Mowrer, 2002). This will result in a higher expenditure of energy over the same distance. Parker-Pope (2008) asks whether individuals are fit enough to cope with this type of scenario.

[8] E.g. UK – Health and Safety at Work Act 1974, Australia – Section 21 Model Occupational Health and Safety Act; See Chapter 3 for further detailed discussion.

[9] As a result of applying an Evacuation Code or Standard

1.2.3 The individual office worker, questions of age and physical condition to complete trial evacuations.

The occupants of high rise office buildings usually comprise white collar office workers whose vocational lifestyle is sedentary (Bee, 2011). A small cross sectional European Study shows that, regardless of an individual's occupation, sedentarism[10] or lack of physical activity during leisure time is as high as 84% (Gal et al, 2005). Bee (2011) shows that sitting at a desk all day can result in many chronic cardio respiratory and metabolic conditions. NSW Health in Australia is concerned about this problem since over 40% of the population are physically inactive and over 50% are classified as obese (Centre for Health Advancement, 2008). Steele and Mummery (2003) in an Australian study confirm that the level of energy expenditure (METS[11]) associated with leisure activity was generally higher for the professional and white collar workers. Their study (Steele and Mummery, 2003), however, was mainly confined to the measurement of energy expenditure of white collar, professional and blue collar workers in the workplace, with the age group of respondents ranging from 18 – 62 years. In discussing the impact of ageing Gal et al (2005) also indicate that increasing age is associated with increased sedentarism[10].In the Steele and Mummery study (2003) over 50% of the white collar respondents exceeded 42.9 years in age and 40.9 years for the blue collar workers. This matches the UK trend where over 50% of the workers over the next decade will be >40 years old with the 50-64 age group accounting for over 30% of the workforce (Dixon, 2003). The same projections also apply generally to New Zealand and North America (Ovseiko, 2008). Is sedentarism[10] therefore a risk factor for those over the age of 40 years and does this mean that over 50% of the workers will be

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[10] i.e. where a person's level of energy expenditure is less than 4 METS. See footnote 13 below for definition of METS.. It is a risk factor associated with a sedentary lifestyle such as an office worker who is not really active during their leisure time.

[11] METS is a measure of human energy. It stands for "metabolic equivalent". A body at rest uses 1 MET to maintain its function. Physical activity over and above this is measured in multiples of METS. The more vigorous the exercise the greater is the METS/minute (energy expenditure per minute.

classified as mature age? The research literature tends to set “mature age” at 45 years (Warr, 1994 and Government of South Australia, 2006).

Al-Abdulwahab (1999) in a study of the functional ability and strength of males showed a marked deterioration of strength and a decrease in functional ability commenced at about the age of 40 years. Pauls et al (2007) is concerned about the impact of age and lack of fitness on stair climbing and this concern is borne out by others who confirm the impact of age and a sedentary lifestyle on the loss of strength and the increase in levels of obesity (Booth et al, 2002 and Lauretani et al, 2003).

The NSW Department of Health (Centre for Health Advancement, 2008) have organised an intervention programme with employers to modify the lifestyle of office workers (white collar and professional) at work through diet, working conditions and practice. Other simpler intervention programmes such as opening up the fire stairs to promote inter floor communication and therefore an option for some vigorous exercise (Eves et al, 2008) could offer other options where energy expenditure levels would be greater than 8 METS. A lifestyle associated with inactivity will speed up the loss of strength (Booth, 2002). The overall intervention discussed above would need to include leisure time activities as well if the level of energy expenditure at work for white collar and professional workers is compared with that of blue collar workers (Steele and Mummery, 2003).

A further examination of the Steele and Mummery study results (2003) reveals that the office worker generally expends 85% less energy in their occupational setting than blue collar workers. The daily level of energy expenditures for office workers confirms sendenterism[10].

Seeing the mean age across all the occupational categories in this study (Steele and Mummery, 2003), was approximately 40 years and, that this is the approximate age where functional abilities start to decrease together with a loss of strength (Lauretani et al, 2003 and Booth et al, 2002), the author considers that it is entirely appropriate to focus the research on the performance of this age group in the descent of stairs in trial evacuations. This consideration is confirmed by the concern expressed by a number of eminent researchers in pedestrian movement (Pauls, Fruin and Zupan, 2007).

1.2.4 The extrinsic factors – the stairs and the surrounding stairwell

High Rise Office Building stairwells for buildings over 25m in height are of fire rated construction[12.] The entry doors are therefore fire doors on self-closing devices. This enclosure needs to maintain this fire rating until it discharges to a place of safety on the ground floor or the level where it leads to a place of safety[12]. In high rise buildings the footprint of the fire stair may change between the high, mid and low-rise sections of the buildings in order to navigate around the mid-level plant rooms. Examination of some of the WTC9/11 Tower 1 and 2 floor plans presented in some post WTC 9/11 incident studies (Averill et al, 2005) confirm this type of layout. The internal stairwell environments contain the stairs which may comprise different configurations (e.g. dogleg and box shape) and stair geometry. Pauls (1984 and 2007) shows the impact that the various extrinsic features of the stairs and the surrounding environment and other people have on the individual. The impact is discussed further in the Literature Review.

The most critical issues in terms of the engineering science studies have been the minimum stair width (Blair, 2010), the width of the goings (treads) (Roys, 2006) and availability of handrails (Pauls, 1984). The health science literature shows amongst other things that the steeper the stair the greater the power exerted through the joints in the lower limbs (Riener et al, 2002) so that strength is an issue (Lauretani et al, 2003).

Most of the earlier engineering science studies have also shown that density is the factor that influences descent speed (Fruin, 1987) but recently one of the post WTC9/11 trial evacuation studies (Peacock et al, 2009) confirmed

[12] Approved Document B. Fire Safety, The Building Regulations for UK; Section C of the Australian Building Code 2011 and NZ Compliance Document C/AS1 Fire Safety.

Pauls concerns re the minimum width of stairs being sufficient for users to overtake the slow movers or allow emergency responders to climb the stairs in the opposite direction without causing a blockage. Peacock et al also (2009) showed that distance had an impact on descent speed.

1.2.5 Others on the stairs at the same time – the group

Templer (1992) identifies the impact that others may have on the individual whilst descending the stairs. Not only does this deal with the number of people on the stairs at any one time, which is known as density[13] (Fruin, 1987), but also the impact of the slow unfit mover being assisted by a group holding up others behind, known as "platooning" (Templer, 1992). Groups have been considered in some studies (MacLennan, 1989; Fahy and Proulx, 2005 and Dwyer and Flynn, 2004), but were not directly concerned with the impact of the slow mover. Boyce et al (2011) studied merging behaviour at the entry into the stairwell. The study showed some interesting group behaviours especially in terms of the pattern of deferment and the impact of different stairwell layouts or configurations. This merging behaviour may have been seen by Peacock et al (2009) as a delay.

1.2.6 The Emerging Research Problem

The Emerging Research Problem is therefore one that comprises the risk associated with evacuation drills in terms of the individual's functional ability and physical fitness. The main question has been asked by the Author in the public arena (MacLennan, 2011) and is similar to that asked by Parker-Pope (2008):

"Do we think we are fit enough to survive a high rise building evacuation using the stairs?"

[13] Strictly defined as the number of people per unit area e.g. 4 persons /m^2

There are others. The general issues identified in sections 1.2 and 1.1 show that the performance of an individual descending the stair as part of a trial evacuation needs to be to be studied in context. so that a framework can be selected to interrogate the literature and establish the research questions, aim and objectives: The context is represented by the factors described in Section 1.2 each of which affect the individual's estimated or actual performance. The contextual factors are:

- Emergency preparedness and health and safety – extrinsic factor.
- The individual office worker (questions of age and physical condition to complete trial evacuations) – intrinsic factor.
- The individual and others on the stairs – the group
- The stairs and the surrounding stairwell – extrinsic factor

1.2.7 Conclusion

The research questions, aim and objectives are developed in the subsequent sections using these contextual factors as a framework. The use of this framework is continued on as part of the study to examine the literature, extract data from the PhD Study Delphi[14] and Focus Groups, to interrogate two user based studies and observations from the WTC 9/11 incident and then to underpin the design and execution of the PhD Study.

1.3 Research Questions, Aim and Objectives

1.3.1 Aim

The aim of the PhD Study is:

[14] The Delphi Group was also used to challenge and/or confirm this framework.

"To study the performance of mature age office workers descending multiple flights of stairs in trial evacuations of high rise office buildings in the context of extrinsic and intrinsic factors[15]".

The main thrust of this aim is to study the performance of mature age office workers in descending multiple flights of stairs in the context of the intrinsic and extrinsic factors that impact significantly on this task similar to those factors mentioned in section 1.2 of this chapter.

1.3.2 Objectives:

There are four Objectives that are used to help in delivering the Aim. The objectives are formed in association with the Research Questions. The Research Questions appear in the next section. The Objectives are listed below with the associated Research Questions (RQ):

Objective O-1 (Refer to Research Question RQ1)

Establish which factors are the main extrinsic factors in terms of their "measured" impact on an individual's performance in terms of their functional ability to safely descend multiple flights of stairs.

The main factors will be established in the literature review in Chapter 2 and then via actual case study and analysis that will involve Delphi and focus study groups.

Objective O-2 (Refer to Research Questions RQ2, RQ3, and part RQ4)

Explore the impact of the intrinsic factors associated with an individual's performance

Many of the intrinsic factors have been established by the author in the previous incomplete study carried out at the University of Technology, Sydney in the 1980's that will be incorporated into this PhD Study as an Explorative Case

[15] The framework representing the contextual factors are further tested by Objective 04 as part of an inclusive planning and assessment toolkit

Study. Additional factors will be added as suggested by others (Booth et al, 2002 and Pauls et al, 2007) and as determined in the literature review and tested further by case study and analysis.

Objective O-3 (Refer to Research Questions RQ7 and RQ8)

Establish the extent and location of group formation together with their size, structure, likely behaviour, and impact on the individual members.

The rate of group formation has been explored by the author as per Objective 0-2 but will be explored further via literature review, case study and analysis. Group behaviour is also of interest in terms of the risk involved with assisting those members who are unable to cope and the estimated threat of the group to members with functional limitations e.g. where members feel too embarrassed to ask the group to slow down for any reason.

Objective O-4 (Refer to Research Questions RQ3 and RQ6)

Establish whether or not the performance of office workers in descending multiple flights of stairs can be measured as a function of a maximum number of storeys that can safely descend without a rest in the context of the relevant extrinsic and intrinsic factors. This level of measured performance is seen as their functional ability.

There is no doubt that this issue has been discussed in the past so that generalisations may have been made from organisation to organisation and internationally. Generalisations need to be underpinned by rigorous study where the practice is built into the research method. Case Study research is such a method (Yin, 2009) so that it will be used as the predominant method in this PhD Study.

Individual human performance is shown in Chapter 2 to be directly linked to fitness, functional limitations and distance to be traversed down the stairs. Self designation of functional limitations and level of fitness is extensively challenged because of the value of self reporting (Sjostrom et al 2005). Validated self reporting and designation tools are available (Ottevacre et al, 2011) and can therefore form the basis of inclusively based planning.

The framework proposed in Section 1.2.6 presents individual performance as the unit to be analysed within the contextual framework using a Root Cause Analysis Model. This model shows up the reasons for alteration in individual performance e.g. an increase in distance often results in fatigue so that any functional limitations that will hasten fatigue will show up. Seeing the framework referred to in Section 1.2.6 is used to search the literature and structure the research its value needs to be tested. The framework is in the form of an Ishikawa Chart commonly used in Health and Safety as a Root Cause Analysis tool to establish the level of success or failure delivered via a process or task. See Section 1.4 for further explanation.

1.3.3 Research Questions

The research questions that need to be addressed in the functional ability model referred to in section 1.2 and the Objectives in Section 1.3.2 together with the analysis of typical trial evacuations are[16]:

Research Question RQ1 (Objective O-1)

What are the extrinsic and intrinsic factors in a high rise stairwell (both physically observed and estimated) that would impact on an individual's performance going down the stairs?

The extrinsic and intrinsic factor classifications are established in two ways. The first is from the literature review in Chapter 2. The results are then compared with the advice reached by consensus from the PhD Study international Delphi Group comprising experts from the two schools of research on stair use of engineering science and health science.

Research Question RQ2 (Objective O-2)

What are the functional abilities and other intrinsic factors associated with an individual that would affect their safe descent and can these be measured (e.g. reduction in descent speed)?

[16] Each research question is provided with a numbered reference as they are referred to again in Chapters 6 and 7.

Two measurement techniques are involved here that can be answered by a validated survey system augmented by focus group and benchmark studies. Descent speeds will need to be measured and compared to show the extent of the impact of functional limitations (Spearpoint and MacLennan, 2012)

Research Question RQ3 (Objectives O-2 and O-4)

Can the level of fitness of an individual be reliably established via self-reporting methods such as that established by Sjostrom et al (2005)?

Establishing levels of fitness using self-reporting techniques can provide unreliable answers so that alternative methods need to be explored (Sjostrom et al, 2005).

Research Question RQ4 (Objective O-3)

Is the task of the descending multiple flights of stairs a challenge for an individual in terms of the impact of the extrinsic factors established by the Delphi Group and how can this impact be measured?

There are conflicting reports of high rise evacuation being a challenge because of contextual factors which may be directly attributed to the risk of falling (Spearpoint and MacLennan, 2012)

Research Question RQ5 (Objective O-1)

What inclusive modifications can be made to the construction of stairs and their environment to improve the individual's performance, confidence and lessen the risk of falling?

The answer could most likely be provided directly from such seminal studies as Templer (1992) but it may not answer the construction requirements required to assist users who may be fatigued because of distance so that findings may need to be enhanced further by focus group analysis.

Research Question RQ6 (Objective O-4)

Is individual self-designation of functional limitations an appropriate evacuation planning tool?

Personal emergency evacuation planning is an example (DCLG, 2007) and self-designation does encourage inclusive participation. This aspect will be explored via literature review and survey.

Research Questions RQ7 and RQ8 (Objective O-3)

What factors increase the risk to group members in assisting others in their group who may be in difficulty?

and

What are the threats to individual performance posed by the group and management?

Pauls et al (2007) is convinced that the population has been less fit and more obese over the last three to four decades which is substantiated elsewhere (Booth et al, 2002) so that the members of a group run the risk of injury from assisting morbidly obese individuals when they are not trained in lifting techniques (Hignett et al, 2007). There may be others which can be investigated further using focus groups.

1.4 Framework for reviewing the literature and directing the research.

The framework is presented in the form of an Ishikawa Chart (Figure 1-1) which is simply a cause and effect diagram (Battino, 2006). It is commonly called a 'fishbone' diagram.

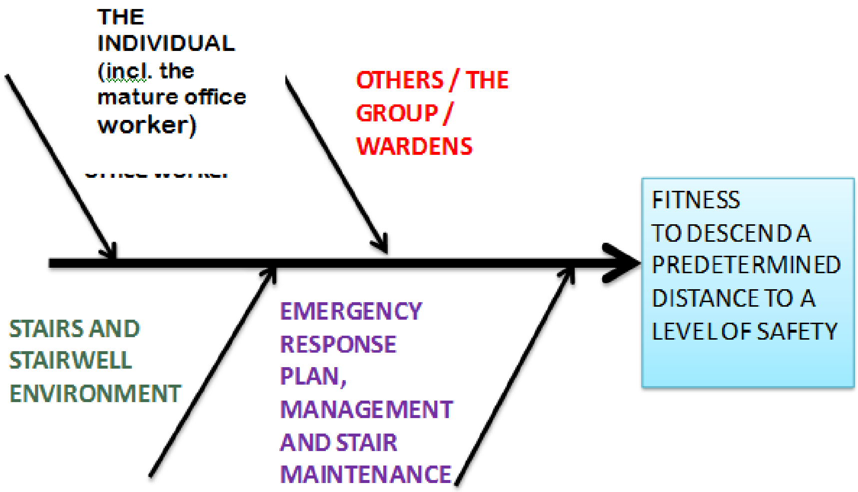

Figure 1-1- Framework for Interrogating the Research Literature where the outcome reflects the Aim of the Research[17]

The main horizontal arrow represents the spine and is where the factors listed on the bones (diagonal arrows) link into the spine. These points are where the interaction between the factors needs to be considered in terms of their effect on the outcome noted in the outcome box highlighted in blue.

Section 1.5 provides an overview of the Research Process and Method. The cause and effect framework provides a view of the context, the classification of which is used to direct the research.

1.5 Summary of Research Process and Method

The scope of work for the PhD Study outlines the work necessary to complete the tasks shown in Figure 1-2 below:

[17] Developed from the Functional Capacity Model developed by Matheson (2003), See Chapter 2.

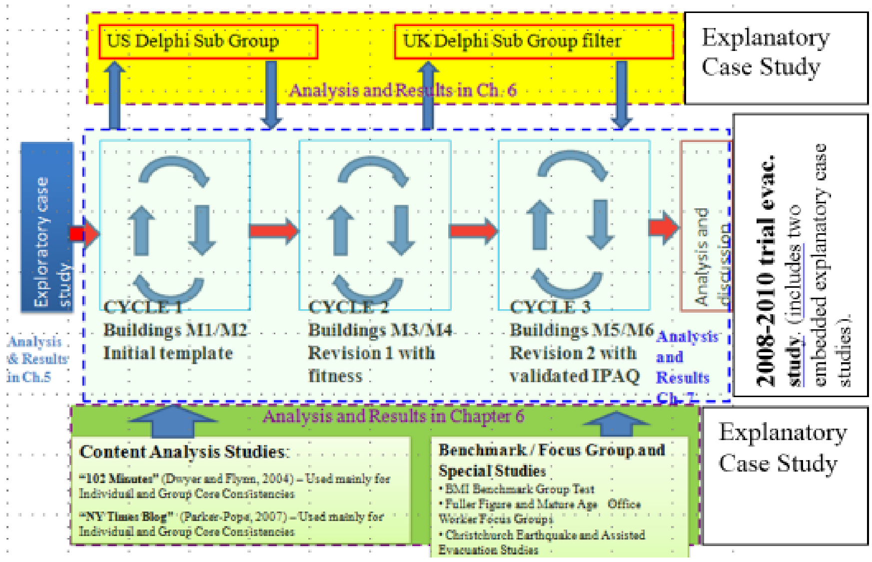

Figure 1-2: Research Process for PhD Study

Selection of the research process and method

The choice of the research method is vital. It not only establishes the extent of the research but provides the rationale for its choice. Figure 1-2 defines the case study process (Yin, 2009). Chapter 3 shows the development of the method using the "research onion" (Saunders et al, 2007) combined with an exploratory case study to test the choices between methods involving the re-analysis of data from a 1980 trial evacuation study carried out by the author. The original aim of this study was similar to that of the proposed PhD study and involved the use of mixed data collection and analysis methods[18]. The Exploratory case study therefore confirmed the choice of methods.

Multiple case studies can be integrated to form one study (Yin 2009) so that this allows for patterns and relationships to be established between buildings and explained by further explanatory studies[19] together with triangulation

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[18] As defined by Amaratunga et al (2002) and Gray (2009)

[19] i.e. trial evacuations in each associated building

between data gathered and analysed via mixed methods (Amaratunga, 2002). Real world studies had been attempted in the past which confirmed the existence of noisy data in stair descent (Blair, 2010; Templer, 1992; Archea, 1979 and Beck, 1977). A real world contextual study of stair descent was therefore required and this is reflected in the aim.

Exploratory case study

The Exploratory case study involved re-analysing hard copy data[20] from a study of trial evacuations in Australia during the 1980's. The exploratory case study showed that the functional ability of the stair user was defined by the distance they had to travel and the resultant level of fatigue they experienced. Their degree of fitness was also unknown. The selection of buildings took into account the existing regulatory definition of high rise as being a building with the height to the uppermost floor of ≥25metres. The group therefore selected 8 buildings ranging from 7 storeys to 45 storeys in height with an average height of 21 storeys (see Figure1-3 below). 45 storeys was the maximum permitted by owners.

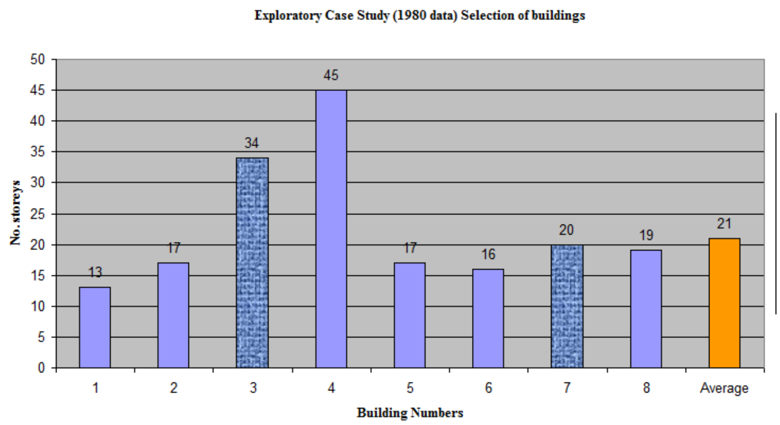

Figure1-3: Selection of buildings from the 1980 study

[20] Original data was stored on magnetic tapes which were dispensed with by the author's previous employer in 1994-1995. The results were not published as the project was incomplete due to the lack of resources and funding towards the programmed end of the project.

Full trial evacuations were held in each one of the buildings[21] and a survey carried out using a questionnaire designed by the group and reproduced in Appendix A5.

Seven extrinsic variables as outlined in Chapter 3 were created from the available hard data along with two intrinsic variables. The frequency tables were reorganised into a master table and patterns established between the buildings that could be explained. Significant relationships could not be established because of the absence of the original data tying the data to each respondent. The trial evacuations also included observers who descended with the groups and they provided strategic times and comments of stair use and actions in accordance with an observation checklist prepared by the group. The only video observations were at the point of final exit so that the time of exit for each observer could be established and descent times established. The lack of intrinsic information gathered from the 1980 data was supplemented by the inclusion of a content analysis of a health science study of three similar office buildings in Ottawa, Canada, carried out by Beck (1977). The Canadian population statistics were compared with the Australian equivalents at the time (Rowland, 1991). The main intrinsic characteristics were found to be broadly equivalent. The Beck (1977) Study was then used to fill in some of the contextual factors and their associated relationships.

The outputs from each study were compared and a combined Ishikawa chart prepared. The rival theory was confirmed and partially explained as density may well have masked fatigue as suggested (Galea et al, 2011). There was sufficient evidence to establish the need for a further current study.

2008-2010 case study

The design sequence of the 2008-2010 case study process is shown in Figure 1-4. The main study comprised the conduct, survey, observation and

[21] Building number 4 was 45 storeys in height so that only a partial evacuation of floors 17-21 and 41-45 were permitted at the same time using different stairs on the grounds of safety.

physical measurement of trial evacuations from six high rise office buildings selected in accordance with the criteria from the Exploratory case study. After detailed enquiries in Australia and New Zealand it was established that 36 storeys was seen by Building owners as being the safe limit for overall evacuations. The selection was such that the 25 storey limit that 50% of the population estimated they could cope with without a rest closely coincided with the average number of storeys[22] of the selection (see Figure 1-4).

The next criteria, was that the buildings should be located in a number of countries where fitness and hence fatigue could be an issue. The USA was investigated as a logical choice but permission was not forthcoming. A decision was therefore made to include a high rise office building in the United Arab Emirates as buildings were generally designed and constructed in complete accordance with Codes from the USA. Also the level of obesity and hence level of physical activity (Booth et al, 2002) was equivalent to the USA. Other countries that were included were the UK, Australia and NZ. The buildings were each given a code number as shown in Figure 1-4 below (M1-M6). The two representative exemplar buildings included for further comparisons from the Exploratory case study were buildings 3 and 7.

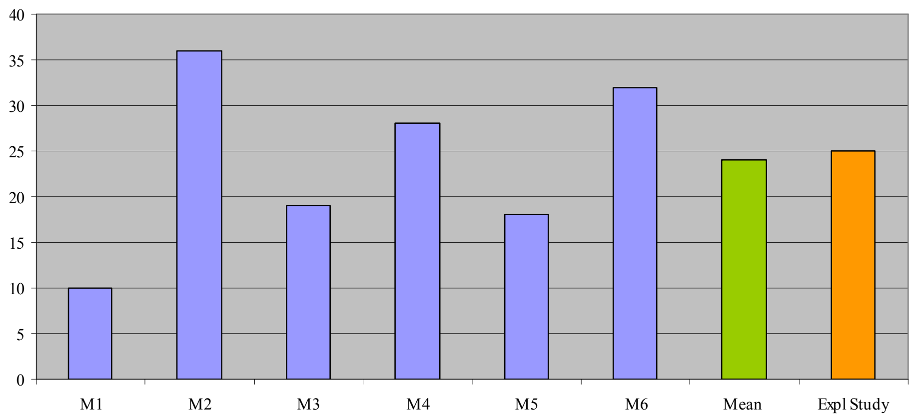

Figure 1-4: Selection of 2008-2010 Case Study Buildings

[22] The average was 24.

Trial evacuations were carried out in all six buildings and data was gathered using fixed video cameras and observers evacuating with the office workers. The observers gathered information on Dictaphones[23] in line with a set of instructions of the observations required during descent. Observers also provided sound "time stamps" at each landing. Questionnaires developed from the exploratory case study questionnaire[24] were handed out and collected about two days later, coded and the data abstracted to spread sheets. The same procedure was repeated for memory cards from the cameras and the sound files from the observer Dictaphones. Stair descent charts such as those in the Appendix A7 were prepared ready for triangulation with data from the survey. Descriptive statistics, regression and factor analysis was used to analyse these data. Details of the analysis may be found in Chapter 3 and 7.

Delphi Group input

Concurrent with the trial evacuations a Delphi Group was formed of international experts[25] to identify the intrinsic and extrinsic issues that affected the performance and/or functional capacity of office workers to descend multiple flights of stairs in a trial evacuation. A variation of the original Delphi approach known as Policy Delphi (Turoff, 1970) was used where the medium of a facilitated committee meeting of experts was used to identify the issues. The opinions of the experts varied[26] somewhat. The process was such that all the issues were identified on the basis that the committee members did not object to their final inclusion. The detailed process is discussed in Chapter 3. The main

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[23] See Appendix A3 for Observer instructions and check lists

[24] See Appendix A3

[25] See Appendix A3 for names and summary CV's of members.

[26] The exact differences were not identified in detail. The differences related to their backgrounds and siciplines.

issues identified were classified as shown on the Ishikawa Chart in Figure 1-1. One other concern was the tools being used to assess fitness. A validated tool known as the International Physical Activity Questionnaire (Sjostrom et al, 2005) was adopted and used.

Focus group and Content Analysis input

The opinions of the experts were complimented by the use of focus groups. The Delphi classifications, other than management, were used as prompts. Three office worker focus groups were assembled as follows:

- **Benchmark** BMI Focus Group
- **"Fuller Figure"** Focus Group
- **"Mature Age"** Office Worker

The **Benchmark** group comprised office workers who were classified as fit using the IPAQ self reporting system (Sjostrom, 2005) to identify this level. This group were also asked to go down multiple flights of stairs as they would in a trial evacuation except that they were on their own. The resultant descent speed was therefore individually selected. On completion of the stair exercise they were asked to complete the same questionnaire as the respondents from the trial evacuations in Buildings M5 and M6 in the third cycle of the 2008-2010 case study (Figure 1-2). Each member also carried a Dictaphone and recorded their progress in the same manner as the observers in the "survey". This procedure allowed their descent speeds to be plotted on a stair descent graph[27] together with any other relevant intrinsic information.

The same process was repeated for the **Fuller Figure** and **Mature Age** focus groups except that the stair descent part was replaced with a walking test where the measured speeds were converted to a descent speed (Riener et al, 2002

[27] The graphs may be found in Chapter 6.

and Fujiyama and Tyler, 2004) because of the safety concerns of the building owner in whose building the tests were carried out. On completion of the questionnaires each member was asked to complete an Ishekawa Chart shown in Figure 1-1 individually with any additional issues to those covered in the questionnaires. The completed documents were returned to the facilitator of each meeting. The meeting was then opened up for discussion (Kruger and Casey, 2000). These responses were transcribed and coded (Insites, 2007).

The data from each of the focus groups was analysed in turn and the resultant descent speeds between the two groups compared. The outcome of the analysis showed that the individual functional capacity and/or performance were different. The reasons for the differences showed up in the questionnaire responses and the analysis of the group discussions[28]. This analysis satisfied the requirements of the Delphi Group re comparisons with descent speed. The data was also used for triangulation with equivalent data from the trial evacuation surveys in the main case study[29]. This comparison provided a measure for establishing the risk of falling for survey respondents[30].

The findings from the focus groups were supplemented by including a directed[31] content analysis of two media instruments (Hsieh and Shannon, 2005 and Fahy and Proulx, 2005). Two instruments were analysed being a record of interviews with survivors and others involved in the WTC 9/11 incident (Dwyer and Flynn, 2004) and a record of responses to a question asked in a NY Times Blog about the physical challenge of descending multiple flights of stairs facilitated by Parker Pope (2007). Most of the issues extracted related mainly to

[28] See Chapter 6

[29] See Cycles 1-3 as shown in Figure 1-2 in Chapter 7

[30] The measure of risk was established where the descent speeds of the survey respondents exceeded the range for the members of the "Fuller Figure" and "Mature Age" focus group members (Mademli et al, 2008)

[31] Directed by the contextual classifications set down by the Delphi Group.

the “group” and the impact of “management”. The frequencies of the responses were established and used to compliment the Focus group findings on an Ishikawa Chart in Chapter 6.

Additional case studies to complement content analysis findings

Two additional author based studies (Yin, 2009) were conducted to enhance the 2008-2010 case study. Case studies are flexible so that when there are contextual issues that require further investigation or explanation additional studies can be undertaken. The matters that required further study were stair width and assisted evacuation involving groups.

Analysis of 2008-2010 Trial Evacuations including triangulation

The analysis of the data from Cycles 1-3 of the 2008-2010 case study comprised the following tasks along with a description of the analysis:

- Data from survey responses were coded and analysed using descriptive statistics[32] to establish frequencies which could then be compared to establish a distinct trend that could be generalised between the buildings.
- Data from the surveys were further analysed to establish internal significant relationships between factors within each classification and then also externally between classifications. This allowed for conclusions to be drawn about the impact of the context on the performance of each individual.
- Coded multi variable data for the stair design and environment classification and the impact on the individual were reduced by factor analysis[33]. Two new variables were derived being descent risk and visibility/ support which were then triangulated with physical measurements taken from each stairwell. The measurement templates are

[32] Using SPSS V16

[33] Using SPSS V16, Varimax method.

shown in Chapters 4 and 7. The triangulation is significant as it confirmed the results from the survey factor analysis (see Chapter 7).

- Video data and observer data were analysed and transferred on to stair descent charts with individual schedules. The charts plotted the path and descent speed of each of the participants in the trial evacuation for each stairwell. The Y-axis of each chart represented height or level number. The X-axis represented the adjusted elapsed time.
- Observer and survey respondent positions and progress were also plotted and determined. Sound files from the observers combined with the sound from the video files were used to enhance information gathered from each individual image. The results were recorded in schedules associated with each stair descent chart.
- The additional internal triangulation permitted the preparation of additional schedules for triangulation with survey data concerned with:
    - Comparison of focus group and trial evacuation descent speeds for respondents whose intrinsic characteristics were the same as the members of the focus groups (risk of falling)
    - Verification of group formation
    - Extent of overtaking and delays caused by slow movers including causes.
    - Verification of conditions in the stairs especially in terms of the degree of crowding via comparison between the measured density (people/m^2 of stair) and the survey respondent estimation of "crowdedness". This provided further information used to explain whether or not the descent speed was physically reduced by "density". The reduction in descent speed coupled with other delays provides opportunities for people to rest thereby reducing fatigue.

Comparisons were made between the distances actually travelled by survey respondents and whether they felt the distance comprised “too many flights”[34] or how the response related to the answer to the direct question in all the questionnaires concerning estimated descent ability[35]. Responses to this question were also analysed to establish the number of storeys that could be coped with by the 50% of the surveyed population. This provides an overview of the level of performance of the office worker as it has a significant relationship with their trial evacuation experience (measured and estimated). The findings from the analysis were determined and are presented in Chapter 8.

1.6 Thesis contents

This chapter introduces the intrinsic and extrinsic issues that impact on the performance of office workers going down stairs in trial evacuations. It shows that these issues were not really considered in previous stair safety and evacuation studies. The research problem is established together with the aim and objectives. The appropriate research method briefly described. The chapter concludes with the cause and effect framework that is used to direct and co-ordinate the research.

Chapter 2 provides an extensive introduction to multi flight stair descent safety commencing with real world engineering science based studies and comparing these with health science based studies carried out in the laboratory. This Chapter is a literature review and shows how these engineering based studies were concerned about stair design and construction issues and safety whilst the health science studies concentrated on the intrinsic issues (age, gender, fitness and health conditions) affecting descent. Rival theories are identified as a

[34] A direct question asked in the questionnaires for cycles 1-3 of the 2008-2010 case study and further compared with the effects of the descent such as fatigue. Also a

[35] Coping – i.e. the maximum number of storeys the respondent estimated they could cope with without a rest – this is taken as a measure of their estimated functional capacity/ performance.

result concerning fatigue and distance. The chapter concludes with the context summarised in a cause and effect framework with individual performance and safety as the outcome.

Chapter three identifies the need for the real world study and the need for the individual office worker to be included as the focus of future research. Various research strategies are examined and a mixed methods multiple case study process selected. The process is described and its component part described in detail. Chapter 3 also introduces the cause and effect framework that is used to drive the collection, analysis and discussion of the data. The chapter concludes with the method used to triangulate the data so as to reinforce findings developed from the individual analyses.

Chapter 4 provides the plans and measured stair details for each of the buildings re-analysed for the Exploratory case study and those selected for the 2008-2010 case study. This chapter also describes the trial evacuations for each of the case studies.

Chapter 5 presents the results of the Exploratory case study being a re-analysis of hard copy data from an author based trial evacuation study carried out in the 1980's. The re-analysis of results of a real world study connected with the origins of the Exploratory case study are presented and integrated with the 1980 results. The chapter concludes with the summary of the results and associated discussion within the cause and effect framework. Possible performance predictors are presented as outcomes using this framework and the selection of the mixed method multiple case study is confirmed.

Chapter 6 presents the results of the embedded explanatory case studies ahead of the 2008-2010 trial evacuation case study results in the next chapter. The Delphi group design and process is described with the outcome of their opinions being the contextual factors of stair descent. The chapter continues with the results from the focus group studies sessions supplemented by two Content Analysis Studies directed by the Delphi Group's contextual classification framework. A quantitative analysis of the focus group tests and Content Analysis factors is presented and integrated with the other results in a cause and effect framework ready for further integration with the 2008-2010 trial evacuation study results in Chapter 7.

Chapter 7 commences with the results of the trial evacuation survey and trends across the buildings M1-M6. Results from the observers and video analysis are included in Appendix A7. The three data sets are triangulated extensively with the details included in Appendix A7. The outcome of the triangulation is presented in Chapter 7 and further summarised and discussed in a cause and effect framework. The chapter concludes with the "analysis" of the trial explanation results within the context of the outcomes from Chapter 6.

Chapter 8 shows how the aim and objectives have been delivered and presents the other significant findings within a contextual framework. The rival theories of fatigue, distance and falling are resolved. Research methodology is reviewed including the associated limitations, the contribution to knowledge defined and the contribution to the future suggested.

Chapter 2 – Literature Review

2.1 Introduction

This Chapter reviews the literature dealing with the performance of individuals descending stairs in the context of a number of associated extrinsic factors. The intrinsic factors associated with the ability and capacity of individuals are also included in the search. The approach is based on a combination of earlier real world research (Pauls, 1974; Templer 1992; Beck, 1977 and Archea et al, 1979) coupled with experimental research nested in health science (Bohannon, 1997; Fujiyama and Tyler, 2004; Riener et al, 2002; and Reeves et al, 2008).

The contextual issues of multiple flight stair descent in trial evacuations have been researched individually but studies with their impact on individual performance but never integrated. This changed with an extensive UK study of the WTC 9/11 incident by Galea et al (2008a). The study is, however of a single incident, and it may not be able to generalise findings because of the specificity of the incident. This chapter looks at other associated studies of this incident (Gershon et al, 2007) where a participative action research method was used. Contextual issues of management and individual performance were raised. When this was coupled with a seminal paper by Pauls, Fruin and Zupan (2007) concerned with how the intrinsic characteristics of the population had changed over the last three decades then it was determined that any potential body of knowledge on multiple flight stair descent needed to incorporate all the issues.

An Ishikawa Chart (Battino, 2006) is used in association with this chapter, as presented in Chapter 1, to clarify and simplify the contextual issues and to show that each of the issues (both extrinsic and intrinsic) can affect the performance of the individual in some way.

In summary the literature search in this chapter therefore examines research carried out in the real world and in the laboratory. The WTC9/11 incident studies provide the tool to link the real world and experimental studies together and apply the findings to multiple flight descent.

2.2 Overview

As high rise office buildings increase in height so does the distance an occupant has to travel from the floor which they occupy at the time of an evacuation alarm to a place of safety. The place of safety is normally outside or a place of refuge within the building[36]. A refuge in traditional terms is one that provides the necessary shelter for a person who is unable to go down the stairs due to certain functional limitations [37]Current amendments to NFPA 5000 (NFPA, 2012) will also permit the use of specially designed elevators. In the United Kingdom guidance is also given in BS5588 Part 2 on the design and installation of elevators for evacuation. These strategies may not always be entirely suitable for every type of emergency where it is possible that the elevators may be taken out of service. This PhD Study does not include an appraisal of alternative evacuation systems. It is only concerned about the use of stairs as part of a trial evacuation exercise most likely required by the relevant Occupational Health and Safety legislation in the light of the WTC 9/11 incident (Averill, 2005).

Research into emergency egress[38] starting with the study of trial evacuations in the early 1970's (Pauls, 1977) and the movement of crowds at the same time (Fruin, 1987) provided the building industry with valuable reference data. The two important aspects of the research was the match between the needs and characteristics of the occupant (individual office worker) and the egress stair and its surrounding environment (Pauls, 1977 and Bukowski, 2009).

International building regulations such as those in the UK, US, and Australasia created a surrounding environment for the stairs where these 'egress' stairs were required to be housed inside enclosed fire rated shafts that in the main led

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[36] E.g. Such as may be required by a Code such as the NFPA5000 Construction and Safety Code (NFPA 2012) or D1/AS1 (NZ Department of Building and Housing, 2008)

[37] Refuge and Fire resistance rating as defined in Approved Document B (Fire Safety – 2006 edition), (Office of the Deputy Prime Minister (2010).

[38] Emergency egress is the act of responding to and safely evacuating the area under threat to a place of safety that is located either outside the building or within the building. The building needs to be designed with the necessary systems to allow this to happen.

directly to the outside of the building or discharged within a safe ground floor area[39]. This form of construction provided a fire resisting barrier to keep people safe as they passed the floor on which the fire was located and to prevent fire from spreading up through the building[39.] Other studies (Proulx et al, 2007) focussed on this challenging environment in terms of providing guidance for the individual in terms of signage and clearly defining the steps in each flight along with the handrails so that the individual could find their way and be provided with support for the such a challenging task (Reeves et al, 2008). More recent studies of two fire incidents (Proulx et al, 2004 and Kuligowski and Hoskins, 2010) show that safe egress involving going down the egress stairs depends on many other elements such as the emergency evacuation and response plan, the associated emergency communication systems and whether or not people are familiar with what they have to do. These two studies showed that the occupants were confused by a complex evacuation strategy and plan.

Office stairs were generally designed to accommodate two individuals to descend side by side (1100mm between walls or equivalent) (Pauls, 1984). This minimum width was based on data gathered over 40 years ago. Pauls has challenged this width based on findings from the WTC 9/11 incident and has shown that this width should be increased to between 1200-1500mm (Pauls et al, 2007). Pauls is supported by other studies such as that of Blair (2010). Pauls et al (2007) maintain that the characteristics of the individual have changed over the last 40 years especially in terms of lifestyle both at work and at home. They (Pauls et al, 2007) simply state that the average body size has changed due to obesity and that people are not as fit as they used to be. Some people are still fit and therefore can go down the stairs at a faster rate than others who are less fit and able. Stairs need to be wider to allow the fitter people to overtake and to allow fire-fighters and other emergency personnel room to climb up the stairs so that they can rescue other occupants who may be trapped on a higher level. The need to increase the minimum width has been confirmed in a more recent study carried out as a result of two main studies the first

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[39] Part 24, Former Australian Model Code developed by the Interstate Standing Committee on Uniform Building Regulations prior to 1979.

by Galea et al (2008) being the UK Study of the WTC 9/11 incident[40] and the second by Peacock et al, (2009) where they showed that the width of the stairs was one of the main reasons for increases in evacuation time.

Peacock et al (2009) also showed that there were still other things that required further research and this was confirmed by Blair (2010) in a separate study using the same raw data from the Peacock et al study (2009). In analysing the data she found that the data was extremely 'noisy' due to other behavioural factors[41] that she was not able to examine any further. One of the examples of this 'behaviour' which has been studied recently is the interaction of the individual with others in such actions as 'merging' when entering the stairs (Boyce et al, 2011). Survivor responses from the WTC9/11 Incident (Dwyer and Flynn, 2004) show the marked presence of other forms of group such as altruistic behaviour[42]. This type of behaviour can cause the group to go down the stairs at a slower rate (Fahy and Proulx, 2005) and possibly test the patience of those behind by holding them up (Parker-Pope, 2008). Conversely it should be noted here that a member of the group may be too embarrassed to ask the others in the group to slow down so that this member may increase their risk of falling by travelling at a faster rate[43]. Group behaviour can even be affected by the emergency evacuation plan where special provisions are made for an individual requiring assistance to be assisted by their work colleagues or other specially trained workers (Kuligowski and Hoskins, 2011).

One of the recommendations made from an analysis of the WTC9/11 Incident made in two separate studies was the importance of the occupants and their

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[40] Galea et al, (2008) mentioned how people were held up by fire-fighters and other emergency responders – problem of counter flow.

[41] Behavioural factors in trial evacuations are the major concern of the thesis, but the number of other factors may quite well increase during an actual emergency. An example of occupant confusion caused by a complex evacuation and alarm system in a real fire is presented by Proulx and Reid, (2006).

[42] Altruistic behaviour here means when members of the group are prepared to and do help another member of their group with some kind of impairment or functional limitation.

[43] Increasing walking speed for mature workers increases the risk of falling due to tripping (Loo-Morrey and Jeffries, 2006). This is to be explored further as part of the PhD Study via the use of Focus Groups.

organisations being prepared for an emergency (Gershon et al, 2007 and Averill et al, 2005). The recommendations from these two studies showed the importance of training where the occupants actually completed the evacuation task in its entirety and that this should be done regularly and that if that involved going down the stairs then the occupants should do so. This would be the only way for everyone to find out whether they were able to cope with the physical challenge of going down the stairs or whether they should be evacuated in another way (wait at a safe refuge, evacuate by properly designed elevator or by some other means) (Gershon et al, 2008). Completion of the evacuation task therefore involves trial or practice evacuations carried out at least once or twice per year.

Emergency preparedness centred on trial evacuations is now a legal requirement for high rise office buildings in such countries as the US, UK and Australasia. This requirement is typically either enshrined in a performance requirement such as in Section 21 of the Model Occupational Safety and Health Code for Australia (Safe Work Australia, 2011) or via a set of prescriptive regulations such as the New Zealand Fire Safety and Evacuation of Buildings Regulations (Department of Internal Affairs, 2008). Where the requirement is performance based (i.e. the employer is required to provide a safe place of work) this is usually reinforced with a Code such as the Australian Standard AS 3745:2010 (Standards Australia, 2010). Usually the occupants are required to practice the implemented procedures at least once or twice per year such as in New Zealand (Department of Internal Affairs, 2008). The UK Fire Safety Reform Order requires fire risk assessment of buildings from time to time. This assessment will involve the development of evacuation strategies and the associated planning and training. The employee is required to participate in the practice evacuation and this means that this participation is one of the conditions of employment (DCLG, 2007).

Gwynne (2008) shows that evacuation procedures need to be inclusive. This means that the occupant needs to be consulted and become involved in the preparation of their own plan. Guidelines already exist in the UK for the preparation of such a personal emergency evacuation plan (PEEPS[44]) (DCLG, 2007a) which cater for those with certain designated 'disabilities'.

The question can be asked as to whether the term "disability" encompasses all the individual characteristics that would place any particular individual at risk going down the stairs twice per year. Some of the functional limitations such as sarcopenia and its associated causes mentioned by Al-Abdulwahab (1999) may not be included or be readily apparent in the definition of disability (e.g. NFPA, 2007). Many studies link lack of fitness, especially for those over the age of 40 years, to such things as strength and stability (Bergland et al, 2008; Browning and Kram, 2008 and Corbeil et al, 2001) so that there may be a greater risk to the individual and also others in their group in requiring any occupant to use the stairs in every trial evacuation which would be held at least once or even twice per annum. This risk may be greater than that associated with a lesser frequency which is during an actual emergency. This is seen as the research question as discussed in Chapter 1.

2.3 Literature Sources

The literature was gathered from a number of sources[45] that were concerned with the study of people going negotiating stairs:

- Health science literature which deals mainly with individual characteristics, functional abilities/limitations and functional capacity.
- Fire safety and science literature where it focuses on both the individual and others/ groups in terms of human movement studies.
- Occupational health and safety literature where it is concerned with emergency planning and organisation

[44] PEEPS is a fully documented set of guidelines covering the process of preparing "Personal Emergency Evacuation Plans

[45] Similar approach used by the author in his contribution to a review article on the impact of obesity and functional limitations on stair use in evacuations (Spearpoint and MacLennan, 2012).

- Architectural literature on stairs and stair environment as extrinsic issues

2.4 Health Science Literature

This literature source is mainly concerned with the stair user (Individual) which is known as a study of the intrinsic issues. It also includes the rights of the individual in terms of health and safety.

2.4.1 Office Workers and their associated activity levels

The occupants of high rise office buildings (office workers) have a style of work that is predominantly sedentary (Steele and Mummery, 2003). Steele and Mummery carried out an interesting study that established the amount of energy office workers expended each day in the work place as compared with those in manufacturing. The amount of energy expended was measured in METS[46]. There are a number of levels of activity that vary in intensity as follows (Australian Institute of Health and Welfare, 2003):

- **Light Intensity physical activity:** Defined as 1-2.9 METS which is taken as walking at a comfortable pace in terms of stepping.

- **Moderate Intensity physical activity:** Defined as 3 – 5.9 METS which is taken as walking at a brisk pace.

- **Vigorous, heavy or rigorous physical activity:** Defined as 6 METS+ which is taken as running, playing squash, and forms of resistance type training.

[46] 1 MET is the energy expended by an individual sitting quietly which for the average adult is 3.5ml of oxygen per kilogram of body mass per minute.

Occupational Category	Step counts (Pedometer)	MET-min-week.	Level of expenditure in METS – min.
Professionals	2855.2±945.7	**3987.2±23.8 (1.1) – 80% less than blue collar**	**1.9**
White collar	3616.5±1519.2	**3590.1±907.2(1.0) - 90% less than blue collar**	**1.71**
Blue collar	8757.4±2540.4	**6704.9±1730.2 (1.9) – baseline for comparison.**	**3.3**

Table 2-1: Mean and standard deviation for energy expenditure associated with physical activity carried out in the workplace by each occupational category. (Source – Steele and Mummery, 2003)

Table 2-1 shows the results of the study which shows that the blue collar workers (manufacturing) expended 95% more energy during their working hours than the white collar workers due to the vigorous nature of their work activity. This study (Steele and Mummery, 2003) only examined activity in the workplace. They did acknowledge that the white collar workers and professionals could undertake a formal or informal exercise regime at home and decrease the risk of the onset of obesity and other chronic conditions (Behre et al, 2011 and Bertrais et al, 2005). There are studies that have shown that the regular daily use of stairs by workers will be of benefit and increase the level of energy expenditure of office workers in their workplace (Eves et al, 2008).

Obesity and age explain most of the association between physical activity and fitness in physically active men (Serrano-Sanchez et al, 2010) so that middle age is a natural point at which the sedentary nature of their occupational category is quite critical especially when they start to lose strength (Al-Abdulwahab, 1999). Lauretani et al (2003) also showed that the number of functional limitations started to increase at this point as well. Increasing leisure time exercise at a vigorous level through the addition of resistance training and stair ascent exercises can reverse the loss of muscle mass in middle age as shown in a study by Melov et al (2007).

The mature age worker as defined by most authorities as generally being over the age of 45 years (Kossen and Wilkinson, 2010). Some mature age worker studies also reveal that over 25% of these workers (Government of South Australia, 2008) will have some kind of functional limitation[47] which agrees with the findings noted in the previous paragraphs.

2.4.2 The Individual – legal obligations of the building owner and the employer.

The review shows that there is a legal obligation for the employer and/or the building owner to provide a safe place of work for each and every worker (US 2009 and UK-ATL, 2011) and that this obligation extends to all workers[48]. The provision of a safe place of work therefore applies directly to making provision for safe evacuation in event of an emergency. There are numerous guidelines available for the employer or building owner and their experts to provide a meaningful inclusive set of evacuation procedures (Standards Australia, 2010; NFPA, 2007; and DCLG, 2007) that most likely will cater for the mature age office worker and all those with functional limitations that may compromise their stair descending ability. The employer needs to be careful in terms of their duty under the law and their potential liability in requiring an individual to go down the stairs during a trial evacuation once or twice per year when the individual may not be able to cope with the physical challenge. A structured evaluation of a worker's ability to go down multiple flights of stairs as part of a trial evacuation exercise should form part of a worker's assessment to make sure that their functional ability match the needs of their job (Matheson, 2003).

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[47] Functional limitations such as impared mobility, lack of descnt confidence due to increased postural sway, increased stress due to the onset of anxiety disorders such as agoraphobia or increased fatigue due to lack of fitness (Booth et al, 2002)

[48] US – Americans with Disability Act; UK – Equal Opportunity Act 2010; and Australia – Federal Disability Discrimination Act

2.4.3 The Individual – general issues in functional ability and limitations.

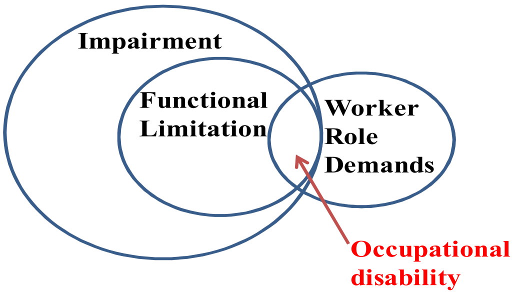


Figure 2-1Assessments of a work disability requires knowledge about the demands of the worker role and the functional limitations of the worker as an individual.
Source: Matheson (2003)

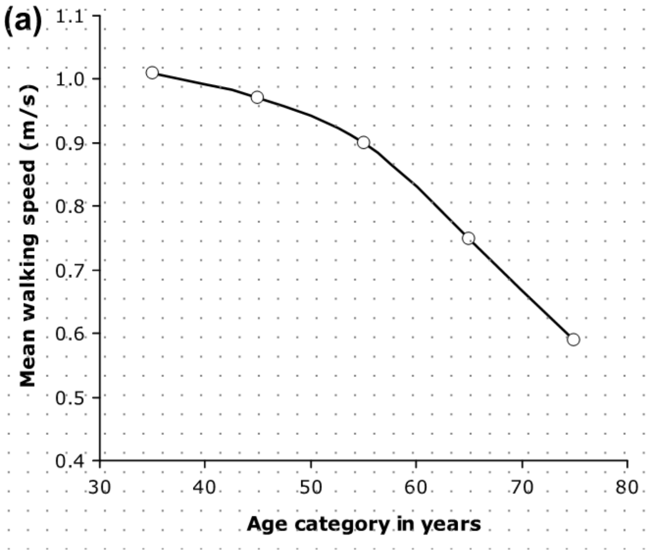
Matheson (2003) developed a model of functional capacity evaluation (FCE) which is described in Figure 2-1 above. The worker role demand would be the mandatory participation in a trial evacuation. The term impairment would include any condition that the employee may consider to qualify as a functional limitation that would impact on their ability to descend the stairs as a first choice. The net outcome would be classified as an occupational disability or as a functional capacity descriptor that could be used to develop an alternative safe method of evacuation. There are engineering science studies that show in a study of the WTC 9/11 incident that an individual's functional capacity (occupational disability) did not prevent them from descending multiple levels of stairs to safety (Shields et al, 2009 and Galea et al, 2008). Galea et al (2008) did qualify this finding as being a specific one because the individuals were able to rest on the stairs because of delays and the slow movement due to overcrowding. Other affects gathered from studies of emergencies (e.g. Proulx and Reid, 2006) show the impact of poor information causing confusion which increase the stress but still do not appear to diminish the onset of altruistic behaviour.

There is also the strategy of self designation where an occupant with severe mobility issues organised her own method of evacuation. She firstly organised a group of buddies to be part of the exit strategy for her floor and had them trained in the use of her evacuation chair. Using this system she was able to exit the buildings safely via many flights of stairs without causing any delays (Zmud, 2007). This is also confirmed by a further study carried out by Adams and Galea (2010) which showed a descent speed of 0.5m/s plus[49].

Walking Speed and functional limitations

Individuals may be able to walk and descend stairs at certain speeds as measured in standard 6-10 metre walking tests (Fritz, 2009 and Graham et al, 2008) but these tests on their own do not necessarily reflect the individual's walking ability which relies on strength, endurance, stability and many other factors (Al-Abdulwahab, 1999). Fitness is not the only issue. Other conditions such as age, gender and obesity and other co- morbidities may limit their walking ability (functional capacity) (Bohannon, 1997; Ayis et al, 2007 and Kang and Dingwell, 2008). Ayis et al (2007 also show the impact of distance in Figure 2 2 below:

[49] Adams and Galea (2011) only tested a 75Kg chair. 200Kg test carried out by Author and described in Chapter 7 with same positive result.



(a) Age category in years versus reduced walking speed

Source: Ayis et al (2007), Table 1, pp. 1907.

(b) Maximum walking time and associated speeds

Figure 2 2: Walking speeds, age and walking ability

Figure 2 2(a) shows the reduction of walking speed increases with age[50]. Figure 2 2(b) may be confusing to interpret but those study participants who were able to walk for a longer period of time were those with the greater walking ability and fewer functional limitations. Walking ability relates to time they were able to walk for without a rest and distance they covered during that time. The less time spent walking illustrates a reduced walking ability. The study (Ayis et al, 2007) also showed that as the participants' age increased together with the number of impairments their walking ability decreased i.e. walking speed versus time spent walking which translates into distance covered in a certain time. This relationship can be clarified further by the relationship between walking speed and specific health conditions in Figure 2 3 below (Ayis et al, 2007):

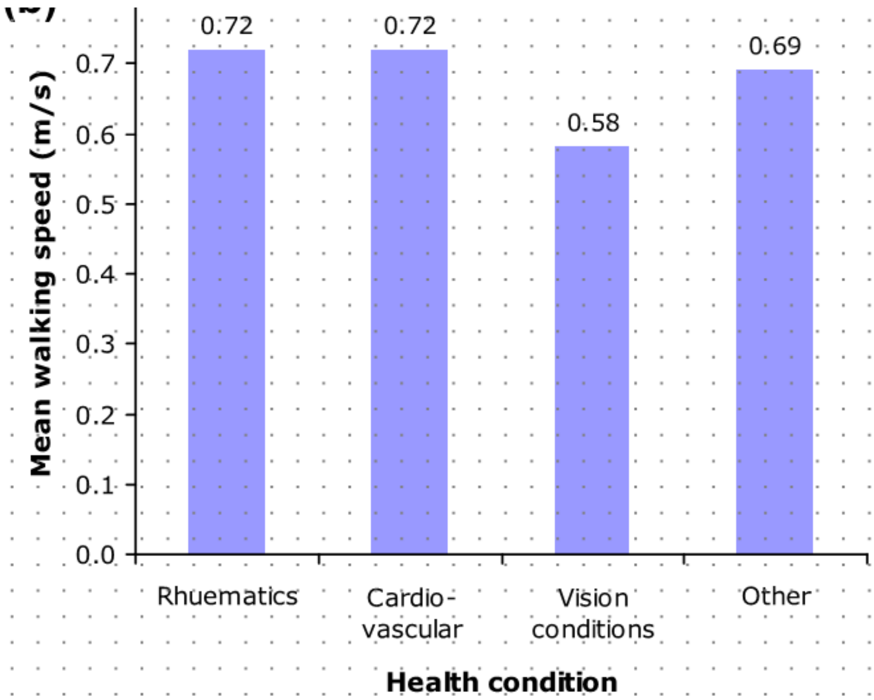


Figure 2 3:- Health conditions or impairments vs. walking speed

Source: Ayis et al (2007), Table 1, pp. 1907.

[50] Also described in other studies as those of Bohannon (1997)

Figure 2 3 (Ayis et al, 2007) shows rheumatic conditions, cardio-vascular problems and reduced vision can reduce walking speed. Hulens et al (2003) show that obesity associated with other health conditions can also affect walking speed and ability especially in terms of capacity and this is where a link may be possible with the engineering science study of Peacock et al (2009) where distance that an individual had to go down the stairs was found to be a major predictor of descent speed. This is also supported by other engineering science databases (Fahy and Proulx, 2001). Walking speed is therefore a good predictor of an individual's walking ability or functional capacity (Fritz, 2009). This was also further supported by the PhD Study Delphi Group (see Chapter 6).

Age and functional limitations

Ayis et al (2007) showed that walking speed reduces from the age of 45 years onwards from 0.97m/sec to 0.75m/sec at 65 years. Much of this is to do with musculo-skeletal pain in the lower limbs. Other studies also show a similar relationship in terms of the loss of strength and linked this with a reduction in walking speed (Al-Abdulwahab, 1999 and Lauretani et al, 2003). Strength plays a vital part in stair descent as can be seen in a study of individuals negotiating stairs at different inclinations. As the inclination of the stairs increased the amount of power concentrated in the joints also increased (Riener et al, 2002). Grip strength correlates strongly with age and the number of functional limitations (Rantanen et al, 1999) and stair climbing ability. A reduction in grip strength can be seen as a reduction in ability to prevent a fall on the stairs by means of taking hold of the handrail (Maki et al, 1998). Reeves et al (2008a) showed that stair users can compensate for this and increase their confidence in descent by placing their hand on the handrail.

Physical Activity and functional limitations

Adiposity and age can explain most of the relationships between age and fitness in physically active men (Serrano-Sanchez et al, 2010)[51]. A basic outcome of

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[51] This change may not be so marked in women according to a study by Van Pelt et al (1998) but it is s relationship that still exists.

a sedentary lifestyle is obesity and this can be associated with and indirectly lead to the onset of many chronic conditions such as cancer, coronary heart disease, hypertension, Type 2 diabetes, and neurological disorders (Booth et al, 2002). He and Baker, 2004 carried out a longitudinal study concerning the level of activity measured over a number of years. They showed that those participants who were obese at baseline increased in mass over the span of the study. This increase in mass comprised the build-up of adipose tissue around the mid region of the abdomen which can increase body sway because of the reduced walking speed. The questions asked in the He and Baker study (2004) were mainly to do with the respondent's degree of fitness and the type of movement e.g. walking or stair climbing.

Increases in fat mass correlate well with a high level of significance ($p<.001$) with reduced walking speeds (Hulens et al, 2003). A classification system developed by WHO (2011a) does not rely on fat mass but on body mass as a function of an individual's height squared. This relationship is known as the Body Mass Index (BMI). WHO (2011a) published an international BMI classification scale:

- < 17.5 Anorexic
- 17.5-18.5 Underweight
- >18.5<25 Optimal
- 25-30 Overweight
- >30<40 Obese 1-2
- > 40 Morbidly Obese

Mchurchu et al (2004) showed that there is a relationship between BMI and the number of associated functional limitations measured over the Asia-Pacific region which included Australasia. A BMI of 35 and above will severely restrict an individual's walking ability or speed as shown in Figure 2 4 below

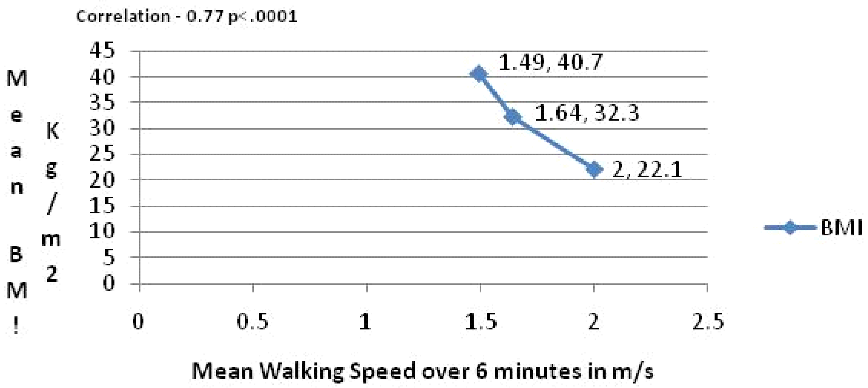


Figure 2 4: BMI vs. walking speed (redrawn from Hulens et al (2007)

As suggested by Booth et al (2002) obesity is a metabolic condition due to a sedentary lifestyle. As an individual's BMI or fat mass increases the lower limb maximal power increases (Sartorio et al, 2004). The descent of stairs therefore can pose a problem for individuals with this condition and they will most likely require rest stops along the way. Riener et al (2002) reinforces this finding where they found that the power concentrated in the joints increased as the inclination of the stair increased. Peeke (2007) would place individuals in this category as most likely being incapable of surviving the physical challenge of stair descent beyond a certain height but in an engineering science study by Galea et al (2011) they reported that only 8% of their respondents descending the stairs when evacuating Towers 1 and 2 of the WTC reported resting due to fatigue. This percentage is still significant but they (Galea et al, 2008) do concede that the need for other respondents to rest may have been offset by the delays due to people entering the stairs and also the number of people on the stairs at any one time with the resultant slow descent speed (Galea et al, 2008a). This is the situation during an emergency as the WTC 9/11 incident was an emergency. The situation can be exactly the same in trial evacuations due to merging (Boyce et al, 2009).

Stability and functional limitations

Stel et al (2003) show that the number of functional limitations affects the prediction of the risk of falling. Menegoni et al (2009) support this finding when they show that as the amount of fat mass increases around the abdomen area so does the amount of body sway thereby affecting the maintenance of postural stability. Menegoni et al (2009) also show that strength plays an important part here in the way the ankles finally have to accept the load when stepping. Moody (2000) also shows that musculo-skeletal pain in the joints can have an impact on postural stability in association with obesity.

Vision impairment increases with the 40+ age group (Leonard, 2002) and a test carried out by Hue et al (2007) shows how poor vision combined with morbid obesity can further increase the risk of falling or confidence in descending the stairs.

MacLennan has further demonstrated in a subsidiary study (2008) that body space has increased along with obesity from $0.28m^2$ to $0.44m^2$. Australian data also supports this increase in spatial requirements (Montgomery and He, 2011). This supports the case for wider stairs put forward by Pauls, Fruin and Zupan (2007) but does not address the increased need for handrail access where two handrails may be required[52].

Stair climbing performance

Balance confidence' and other neurological conditions may affect gait (Verghese et al, 2008).

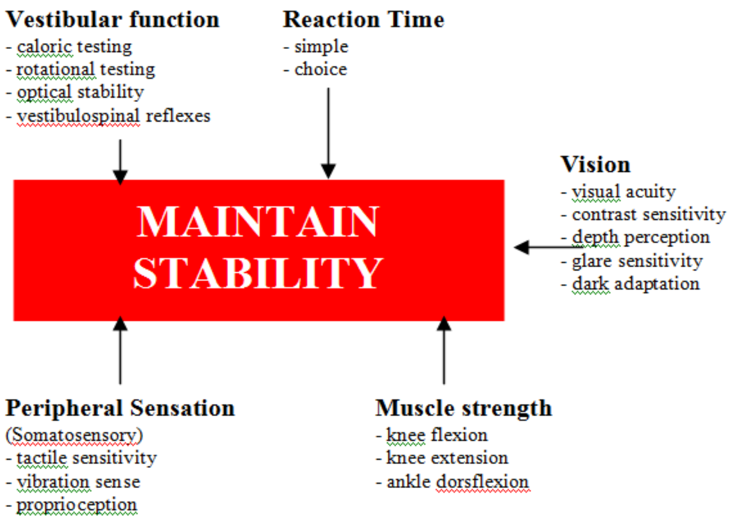


Figure 2-5: System for maintaining stability - the inter-relationships ***(Source: Lord et al, 2007)***

[52] Observation from the Author's 1980 Research Project which is included in the database for the Exploratory Case Study to be analysed in Chapter 5.

Climbing steps not only places demands on the cardiovascular and musculoskeletal systems but also requires input from other systems such as vision, vestibular and somatosensory systems (see Figure 2-5). As people age these systems deteriorate (Hamel et al, 2005). Climbing steps depends on the strategy learnt by the user (Roys, 2006). If the user or person is in a hurry or does not focus then they are not in control and may fall. This can be the case with a slow mover in a fast moving group which can occur in a lightly populated building or where a sequential evacuation is planned[53]. In this case vision can be crucial in the successful climbing of any set of stairs (Startzell et al, 2000).

Bergland et al (2008) see the successful climbing of steps as:

- Generation of concentric muscle forces to "propel" the person up the steps.
- Generation of the necessary eccentric muscle forces to control the body going down the steps especially in terms of controlling the body's centre of mass with a constantly changing base of support forming part of the "action" component of the Templer construct (1992).
- The capacity to adapt strategies to control posture/ stability when the steps and their surrounds result in steps being steeper or support not being available due to the absence of a reachable handrail due to distance or obstruction by another person in the group.

The role of vision may be crucial but it is the degree of focus on the task in hand and maintaining their posture that will determine if the person will be successful. The task of climbing can be divided into three phases as for walking being stance, swing phase and a period of double support as shown in Figure 2-6 (Trew, 2005). It is similar to the activity of walking in terms of the movement of the

[53] Sequential evacuation is when entry into the stairs is in a set sequence with an appropriate time delay in between each permitted entry. The idea is to limit the hazards due to overcrowding.

joints and action of the muscles. As a task the climbing[54] of steps (Figure 2-7) is far more demanding than walking due to the increase in the range of movement on the lower limbs especially the joints and therefore their structures need to be fairly robust if the climbing activity is to be safe (Costigan et al, 2002).

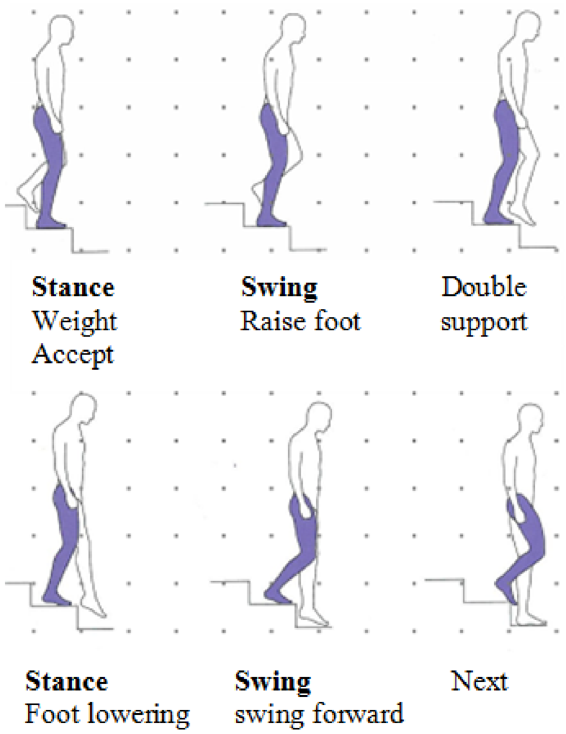


Figure 2-6: Example of 3 phases taken from Trew and Everett (2005) pp. 188

There is a single stance phase in the climbing[54] of steps when the body is vulnerable. This is because the "base of support" is extremely small (Trew 2005). The vertical relocation of the centre of gravity also occurs during the single stance phase so that this requires a great deal of strength, one of the main systems required together with the vestibular system to remain stable (Trew 2005).

Climbing down the steps is an extremely dangerous task in that it results in 75% - 80% of falls on steps (Bergland et al, 2008; Tiedemann et al, 2007; Ozanne-Smith et al, 2008; and Reeves, 2008). Going down the steps (Templer, 1992) the individual starts by placing the leading foot near to or on the first nosing of the

[54] Climbing in this instance includes both ascent and descent

flight[55] at the junction with the landing. Relying heavily on visual and somatosensory inputs they allow their back foot to swing into the air over the line of the first nosing ready to be placed on the first step. At the same time the climber bends the knee of the supporting leg and raises the heel off the landing or path. The other foot is adjusted for position based on somatosensory feedback and placed on to the step. At this point the mass is transferred on to the new leading foot. The rear foot is now lifted off the step above and swung over the next two nosings. The clearance by the toe above the nosings will once again rely heavily on the somatosensory feedback amongst other things and ageing can impact on the performance of these systems (Hamel et al, 2005). Uniformity of riser height is also critical as it is in ascent because as the climber continues on down the flight they learn from the proprioceptive feedback they receive (Roys, 2006). Problems can arise when the individual's vision is obstructed by others or there is lack of definition or contrast between the steps and handrails (Alderson, 2010).

Stair descent therefore calls upon contributions from vision, peripheral sensation systems, vestibular senses, muscle strength and reaction time as well as using cognitive skills to process the associated extrinsic information from the stair construction, configuration and shaft environment. These functions start to deteriorate from 40 years onwards and begin to increase the likelihood of falls. Increasing the level of fitness as part of a structured programme can assist (Peeke, 2007).

Neurological disorders are a group of conditions that involve the central nervous system (CNS) and the peripheral nervous system (PNS) (Patts, 2000). Any impairment will decrease the individual's capability to safely climb steps seeing without adequate training the risk of falling due to a misstep, stumble or slip will increase (Startzell et al, 2000). Researchers have shown that neurologically intact people adapt movement strategies they use for going down steps in response to changes in sensory information they receive about the descent task (Shumway-Cook and Woollacott, 2007). The somatosensory system is as shown in Figure 2-5.The somatosensory system is part of the PNS (Patts, 2000). The awareness of the position

[55] See double support in Figure 2-6

of our limbs and joints in space is provided by information from various receptors in the joints and the muscles passing over the joints (Lackner and DiZio, 2000). Vital information is also received from the head, hands and feet. The feedback from the feet for example is vital for descending and ascending steps as well as walking as it tells the person in combination with visual cues where to place the foot even to the point that the foot is accommodated on the tread (Roys 2006). This feedback process is known as proprioception (Shumway-Cook and Woollacott, 2007). The first step in the flight therefore requires complete focus. As the person proceeds up or down the steps they learn from the information and may adopt a strategy thinking that all the steps will be the same (Roys 2006). If the visual cues are limited then proprioception can still be used to “feel” the position and location of the next tread in space and a decision can be made to modify the gait pattern (Shumway-Cook and Woollacott, 2007).

The somatosensory system can be impacted by neurological disorders as it is part of the PNS (Patts, 2000). These disorders in older people can take the form of dementia, movement disorders, muscle and neuromuscular junctions as well as the PNS itself. Epilepsy is an example. These disorders can be characterised by losses in co-ordination, delayed muscular response, cognitive difficulty and dysfunction, and most of all signification reduction in the somatosensory system which will affect proprioceptive feedback from the steps themselves (Startzell, 2000).

2.5 The Individual – Co-morbidities

A co-morbidity in this context is synonymous with a health condition or impairment which can be made worse by a sudden increase in the level of energy expenditure e.g. going down multiple flights of stairs as part of a trial evacuation. This can be linked directly with the impact of the group where the individual increase their gait because they are too embarrassed to ask the others to slow down. In doing so, they increase their risk of falling[43].

2.5.1 Obesity

Obesity is linked to a number of chronic diseases such as hypertension, type 2 diabetes, some types of cancer, osteoarthritis, osteoporosis, and coronary heart disease (Ewing et al, 2003). In the US 31.1% of people over the age of 60 years were obese in 2003-2004 (Ogden et al, 2006). The rate of obesity in the 40-59 age group was even higher being 36.8% (Ogden et al, 2006). In the UK the rate of obesity has trebled since the 1980's and over 50% of the population are either obese or overweight (Melzer et al, 2006). The same study also demonstrates how obesity, which is now classified as an impairment under the WHO classification framework (Forhan, 2009), reduces life expectancy for adults <70 yrs. by 6-7 years.

In summary morbid obesity (BMI>35) has been included as part of the objectives because of its association with other co morbidities and the impact these can have on the functional capacity of the individual to successfully go down the stairs.

2.5.2 Musculo-skeletal

Musculoskeletal pain experienced by obese and morbidly obese women exceeds that experienced by their leaner counterparts after completing the 6 minute walk test (34.9% as compared with 11.4%) (Hulens et al, 2003). A further study showed that musculoskeletal pain did not necessarily limit the number of activities undertaken by older women but that in certain instances it accounted for them having difficulty climbing steps (Leveille et al, 2007). Although this mainly applies to older women its impact is relevant in the 50+ age group. This can be confirmed especially when the activity involves climbing up a flight of steps where the most striking difference between this activity and level walking was when the peak patella-femoral contact force increased by a factor of eight (Costigan et al, 2002).

Joint flexibility is the one that is most affected by joint seizures such as osteoarthritis and rheumatoid arthritis. Isaacson et al (1988) shows the impact that this can have on the climbing of steps and that it was the knee that had the most impact.

When joint disease is associated with loss of strength and is also due to ageing then the pitch of a flight of steps is quite critical. Riener et al (2002) shows that there is an increase in the power exerted through the lower extremity joints as the inclination increases and that an inclination of 37 degrees could be quite uncomfortable for those with arthritis.

Musculo-skeletal conditions are therefore considered to be a co-morbidity that should be included with the objective that tests the aim of physical fitness vs. distance traversed down the stairs.

2.5.3 Cardio-vascular

Fjelstad et al (2008) studied a group of non obese and obese people with the following metabolic conditions (Table 2-2)

Condition	**Obese (N= 128)** *Mean mass = 100.5Kg / Mean BMI = 35Kg/m2*	**Non Obese: (N= 88)** *Mean mass = 63.5Kg/ Mean BMI = 22.8Kg/m2*
Hypertension	51% (2.2X)*	23%
Diabetes	13% (2.9X)*	4.5%
Hyperlipidaemia	48% (1.5X)*	31%
Fall history	27 %(1.9X)*	15%

Table 2-2: Subject characteristics in Fjelstad et al (2008) Study.

Indicates factor by which the condition is prevalent in the obese group as compared with the non-obese.

The two groups in Table 2-2 were of a similar height and the differences in the BMI were highly significant ($p<.001$). The conditions correlated relatively well with BMI and therefore collectively with functional capacity including the rate of falling. These conditions are generally classified as metabolic conditions (Booth, 2002).

Any cardio-vascular condition such as hypertension, Hyperlipidaemia, reasonably advanced Type 2 Diabetes (with peripheral neuropathy) and where the individual had an associated history of falls studies such as Fjelstad et al (2008) would indicate that any cardio- vascular condition could comprise more than a single co-morbidity and therefore should be used as an objective to test the aim of fitness vs. distance as a measure of stair descent capacity.

2.5.4 Vision

The visual system also plays an essential role in providing people with information about where their bodies are in space i.e. “visual proprioception” (Shumway Cook and Woollacott, 2001). The visual system therefore reinforces or confirms information sensed via the somatosensory system. (Lord, 2007). It helps to the individual to maintain their balance by continuing to provide them with information about their motion and so the “visual proprioception” feedback continues (Lord, 2007). Impaired vision can be associated with postural sway (Lord, 2007). Menant et al (2008) reveal that when people stand with their eyes closed their sway increased by 20-70% thus substantiating the above considerations.

Simoneau et al, (1991), studied the impact of degraded visual acuity on foot clearance between steps. There were three conditions, one where there was no marking of the nosings, one where each step was slightly defined and the last where the nosing was marked by a 38mm wide contrasting stripe. As the step definition increased so did the cadence, foot placement and clearance. With less step definition the person adopts a more cautious approach and places the foot further back on the tread and increased the height of the foot clearance in mid swing phase. Startzell et al (2000) explain the relevance of visual acuity and contrast sensitivity by suggesting that the visual field can be subdivided into the focal or central field and the peripheral field. The focal field serves the functions of visual acuity, contrast sensitivity, colour, pattern and obstacle discrimination. Visual acuity tests measure fine detailed vision; contrast sensitivity tests assess the ability of a person to detect edges under blurred or low contrast conditions (Lord. 2006). A loss in edge contrast sensitivity which can quite easily happen to older people may result in tripping over steps and other obstacles (Lord, 2006). Another central or focal field function that is even more critical is the use of their stereoscopic vision to define depth and distance (Startzell et al, 2000). Impaired stereo acuity or depth perception has a strong association with falls for older people (Lord, 2007). The age group of 55years and above is included here (Lord, 2007).

Gaze stability refers to the stabilization of the eye in space in order to see clearly. As a person climbs a flight of steps or even walks across a level surface the head will move (Herdman, 1997). The more an individual's head moves the more the vision blurs. Blurred vision is just poor visual acuity. A study carried out by Buckley et al (2005) showed that people with blurred vision were more cautious and tended to "feel" their way down the steps. Further Buckley et al (2005a) shows that the medial-lateral stability problem that older people and mature office workers have is further compromised by blurring vision especially when climbing down the stairs (Marigold, 2006)

The use of eyewear can affect depth perception (Studenski and Wolter 2010). In fact, Studenski and Wolter (2010) show that any form of visual impairment can contribute to instability. The single or unexpected step is considered to be a risk. Cowie et al (2008) show that there is a visuo-motor process that a person uses to control a single step. In fact, Cowie et al (2008) showed that a person can actually "scale" the height of the riser as a function of the anticipated height that their knee will "drop" to the next level. Blurred and monocular vision can significantly affect scaling so that single steps are clearly a hazard. Even short flights of two or three steps appear to cause problems (Templer 1992). Single steps should be avoided as part of a multiple flight system where there is a change in flight length or at a point where the stair shaft changes location e.g. from high rise to midrise section.

The use of multi focal glasses can severely impact depth perception (Menant et al, 2008). This issue should be raised with individuals who wear multi focal glasses especially where steps are not clearly defined and the goings are less than 280mm.

Based on this section any type of vision impairment needs to be seen as co-morbidity especially in relation to the risk of falling and/or stability. The presence of others on the stairs will interfere with visibility of the steps and the availability of the handrail will be crucial. It therefore needs to be part of the co-morbidity objective used to test the aim of fitness vs. distance traversed down the stairs and also triangulated against the extrinsic factors of the stairs and stairwell.

2.5.5 The vestibular system and stability or balance

The reader is requested once again to refer to Figure 2-5 showing a schematic working of the systems governing balance.

The vestibular system is located in the inner ear and comprises the non auditory part of the ear that is responsible for a person's awareness of the orientation of their head in terms of gravity and its linear and angular acceleration (Trew and Everett, 2005). It therefore helps a person to maintain their:

- Posture
- Joint stability
- Balance
- Bi-lateral co-ordination (using both sides of our body which is especially the case for step over step climbing of steps.
- Awareness of body position
- Gaze vision (focus) and attention
- Rhythmic movement.

The vestibular system works in tandem with the somatosensory and vision systems but can adapt when the other two systems are impaired e.g. walking on uneven ground in the dark. The vestibular system is trainable as it is evidenced in the rehabilitation of patients recovering from a middle ear infection. Therefore if any one of the other two systems be impaired then vestibular system can be trained to compensate.

Balance is the maintenance of stability. Vertigo and dizziness or "light-headedness" are the main vestibular disorders that may require attention (Bredenkamp, 2009). Normally a person receives information from the somatosensory, vestibular and visual system at the same time. When there is a mismatch it can itself create a sensation which is commonly described as vertigo, dizziness or disorientation (Yardley, 1994). If the mismatch is attributable to an intrinsic dysfunction then the condition is usually labelled as vertigo (Yardley, 1994 and Bredenkamp, 2009). The overall incidence of dizziness, vertigo and imbalance is 5-10% increasing to 40% in people above 40 years of age (Samy and Hamid, 2010).

Yardley and Redfern (2001) in reviewing evidence of psychological factors interfering with recovery from conditions such as dizziness and vertigo show up some connections between heightened anxiety and complaints of dizziness. A common response to bouts of dizziness is to avoid the activity entirely. Anxiety[56] can also increase the degree of a balance disorder.

A vestibular disorder may not be readily apparent such as the onset of dizziness which can be exacerbated with the amount of activity associated with the descent so that it needs to be considered as a co-morbidity objective that will be used to test the aim of fitness vs. distance traversed in descent.

[56] Heightened anxiety is known as Agoraphobia and an instance of this is described in the Exploratory Case Study in Chapter 5.

2.6 Others on the Stairs (Group)

This section will deal with group dynamics in trial evacuations and mainly draws on cognitive science and engineering science literature.

2.6.1 Group formation, dynamics and cohesion in general

It is necessary at the onset to examine the social and organisational context of the occupancy on each floor or group of floors in each building so as to discover the unique characteristics of how the groups are formed in event of an emergency or trial evacuation (Jones and Hewitt, 1985). There is a clear distinction that can be drawn between the situational and authoritative formation of groups and their leaders (Jones and Hewitt, 1985).

Templer (1992) discusses the phenomena of "platooning" associated with groups at the point of entry. The group may form either on the floor or at the entry to the stairs. There may already be a group coming down the stairs but they could quite well defer if the group from the floor has already started to enter. The opposite can happen. It all depends on the size and amount of interaction within the group according to a series of experiments carried out by Knowles et al (1976). Templer (1992) however goes one step further by showing that even smaller groups will still "appear" to occupy the full width of the stair at the entry point. Depending on the amount of interaction within the group this will also affect its "permeability" (Knowles et al, 1976). Other stair users may therefore slow down when they estimate that the group in front of them is impermeable. Merging patterns therefore will depend on the configuration of the stairwell especially in terms of the positions of the entry points in relation to the stairs (Boyce et al, 2011).

The emergency response plan and procedures may define the authoritative group formation under a specific set of procedures as defined for example under a guideline document or standard such as AS 3745[57] (Standards Australia, 2010).

In an uncontrolled evacuation (Pauls, 1988) all floors are evacuated at the same time and the occupants are permitted to enter the stairs when they are ready to do so. The formation of the group in this instance falls into three categories (Jones and Hewitt, 1985);

- Social bonds – friendships between workers
- Organisational structure/ work team – interaction between the structure/ team and the individual's role
- Location in the building at the sounding of the 'alarm' and proximity of others – situational.

Jones and Hewitt (1985) focus on leadership or decision making. They argue that the leadership of a group may correspond to the roles assigned by the organisation. Group formation may be situational or will comprise a group of friends or colleagues. Regardless of the way the groups are formed they tend to behave mostly in an altruistic fashion when others require assistance (Dwyer and Flynn, 2004).

There are also instances where there has been lack of practice or training that group formation will be more situational as shown in survivor recollections from the WTC9/11 Incident (Dwyer and Flynn, 2004). It is interesting to note that up to 27% of the WTC9/11 respondents studied by Fahy and Proulx (2005)

[57] AS 3745 is an official standard where standardised strategies for evacuations are set out especially in terms of sequential and uncontrolled evacuations. They also set out the structure of the emergency team and the roles of the members.

were influenced by authority figures which were defined by the corporate structure of their organisation.

McConnell et al (2010) provide some interesting information on group formation from the WTC 9/11 incident under an activity they called “grouped together”. The global percentage of occupants undertaking this activity was approximately 14%. A potential leadership pattern emerged comprising those with either a fire safety or managerial role. The formation of groups increased on the upper floors. Perhaps this may have been due to their perception of risk. Aguirre et al (2011) argue that behaviour in emergency incidents should therefore be explained by group level considerations so that emergency evacuation training perhaps should make use of this finding as shown by Gershon et al (2007) in feedback provided by WTC 9/11 incident survivors.

The issues discussed in this section will need to form part of the objective that will be used to test the aim of fitness vs. distance to be traversed.

2.6.2 Altruism

Fahy and Proulx (2005) provide strong evidence to support altruistic behaviour when they mention that many of the survivors from the WTC 9/11 incident reported that they had helped other people down the stairs regardless of where the groups were formed. Based on an analysis of assisted evacuation carried out by Adams and Galea (2010) the descent speed of the group assisting would be reduced by over 30% without accounting for any other fatigue factors. An individual requiring assistance could arrange with the members of the group for them to assist so that this group could practice this assistance. An example of the use of the above device in the WTC 9/11 incident has been reported by the National Fire Protection Association (NFPA, 2007 and Zmud, 2007).

The above example shows the need for this risk to form part of the PhD study only in terms of the likelihood of such an individual insisting under a

PEEPS[58] regime (DCLG, 2007a) that they have the ability to evacuate using the stairs without assistance and possibly placing others at risk. The author has also selected the contents of a facilitated blog site (Parker-Pope, 2008) dealing with the use of stairs during trial evacuations. One of the core consistencies of this discussion was the absence of altruistic behaviour tendencies amongst some of the participants. The author intends to analyse this record of discussions in Chapter 6 in association with Focus Groups.

2.6.3 Merging behaviour

Zmud (2007) reports that during a building evacuation via the stairwell one third of the respondents to their survey would be prepared to give way to a group of people coming down the stairs from the storey above. Boyce et al (2011) state that as a result of three evacuation drills they conducted in their study that the merging was about 50:50. The patterns over the merging period were different. These differences were due either to the configuration of the approach of the group entering from the floor and those descending from the floors above or the manner in which groups gave way to each other. This aspect also needs to explore the group dynamics as well in terms of the group size and distance between them at the likely point of merging as the pattern of deferment can also depend on size and degree of separation (Knowles et al, 1976).

Merging depends on the evacuation strategy i.e. uncontrolled stair entry as shown in Figure 2-7 where one group may quite well defer to the other and in a sequential stair entry where the sequence is defined by the emergency plan (Pauls, 1984) as shown in Figure 2-8 below:

[58] PEEPS is an abbreviation for a personal emergency evacuation plan and is needed especially for all those with functional limitations.

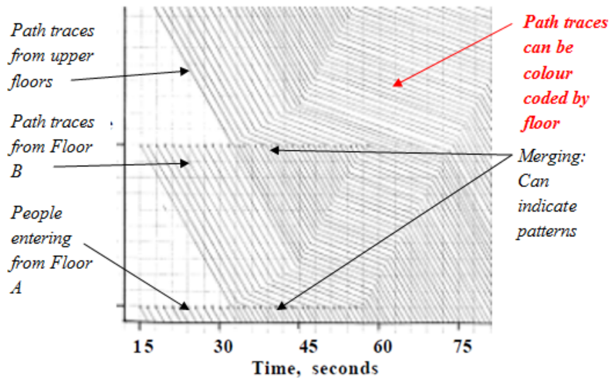


Figure 2-7: Traces of Occupant Movement Showing Mixing and Merging at Entry to Stairs *(Source: Pauls, 2004, Figure 3)*

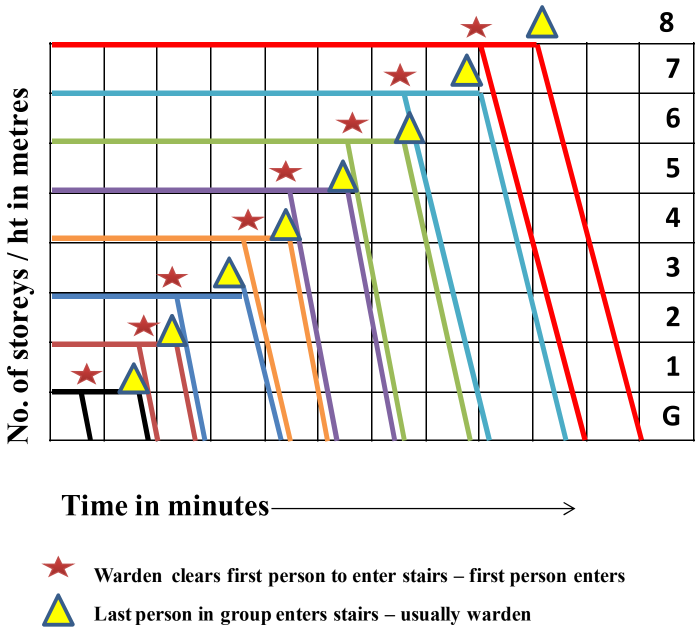


Figure 2-8: Idealised sequential evacuation commencing at ground floor with stair wardens allowing first person into stair once the last person from the floor below has started to descend *(Redrawn and modified from Pauls, 1985)*

From studies such as Dwyer and Flynn (2004) deferment may not be an individual decision but possibly a group decision. Deferment behaviour is also confirmed by Boyce et al (2011) and can be defined by the footprint of the stairwell. Pauls (2004) states that there may also be cultural differences e.g. level of courtesy. Congestion will increase as more and more individuals access the stair as there are spatial factors e.g. personal space requirements, which come into play (Fujiyama, 2005). Descent speed may slow down as a result of this and also because of the delays caused by the merging behaviour.

2.6.4 Can groups constrain flow or is it just the number of people?

Up to 70% of crowds move in groups (Moussaid et al, 2010). It is therefore quite feasible that the descent speed of a group could be determined by the slowest mover based on the social interaction. Fahy and Proulx (2001) show typical walking speeds for people with functional limitations that are much less than those defined by density or the number of people on the stairs. Proulx et al (2007) also confirm the impact of the slow mover in a trial evacuation exercise where there were two individuals who were distinct slow movers where the resultant descent speed was much less than that associated with the measured density in the stairs.

Galea et al (2011) maintain that as density increases there is a point where other characteristics such as fatigue and obesity can be masked. It is argued that the same applies in the case of a group with a slow mover. Density has normally been shown to directly impact on walking speed as shown in Table 2-3(Pauls, 2004).

No. of persons	Density (persons per m^2)	Speed (m/sec)	Flow (persons/ sec)
4	0.45	1.3	0.82
6	0.68	1.2	1.14
8	0.91	1.1	1.4
10	1.13	1.0	1.6
12	1.4	0.9	1.8
18	2.0	0.6	1.7
24	2.7	0.3	1.13

Table 2-3: Speed vs. Density and Flow (Pauls, 2004)

Table 2-3 can be redrawn as a graph (Figure 2-9) and slow mover speeds superimposed on it so as to highlight the impact a slow mover could have on others following them down the stairs. A large group or platoon would then form behind the slow moving group giving the impression of an increase in density (Templer, 1992).

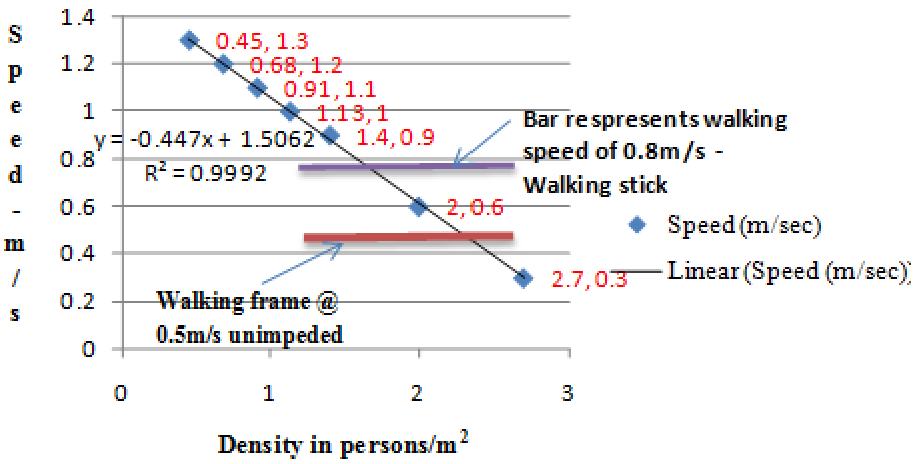


Figure 2-9:- Speed vs density - slow mover comparison

(Drawn from* Table 2-3 *with mean unimpeded walking speed for individual with walking stick and walking frame for comparison only)

Slow movers can therefore determine the descent speed of the group. This could annoy others following them down the stairs especially if the slow mover is obese. Group attitudes in trial evacuations may have an impact on the individual especially if they cause a delay[59] (Parker-Pope, 2008). This is further confirmed indirectly by Puhl and Brownell (2001) and directly by Puhl and Heuer (2009) via statements such as;

"Obese individuals are highly stigmatized and face multiple forms of prejudice in the United States ……The prevalence of weight discrimination in the United States has increased by 66% over the past decade……"
(Puhl and Heuer, 2009, pp. 941).

The above attitude, however, is contradicted by the altruistic behaviour shown by some survivors from the WTC 9/11 incident (Dwyer and Flynn, 2004). It should still be borne in mind should the resultant delay be longer than the following group is prepared to wait that this type of antagonism may occur as shown in an on line chat room Parker-Pope (2008) hosted on evacuations by stairs.

2.6.5 Risk of Groups to their Members

Kang and Dingwell (2008) show that reduced walking speed with ageing does not necessarily improve stability but they did provide a reason for older people decreasing their walking speed. The strategy was to improve visibility. There is still a possibility that individuals will fall if they "rush" (Templer, 1992) due possibly to lack of focus and therefore visibility. Groups do however increase density in the immediate area they occupy and also partly obstruct the

[59] Reactions are normally altruistic as per Dwyer and Flynn (2004) except that this finding may not be capable of being generalised across all incidents. Parker-Pope (2007) shows that this may be the case based on inbuilt community attitudes.

view of other members. If the member of the group is a slow mover that is too embarrassed to ask the others in the group to slow down then they may quite well attempt to keep up with the group and "rush" as a result. Bohannan (1997) shows the variation in walking speeds for adults between 20-79 years. Ayis et al (2007) shows the impact of age and other functional limitations on walking ability. Walking capacity / ability also relies on strength, endurance and stability (Al-Abdulwahab, 1999) so that as the distance to be traversed increases[60] the descent speed slows due to fatigue and/or loss of strength and the risk of falling increases (Lord et al, 2007). Keeping up with the rest of the group therefore requires greater effort and increases the risk of falling. The other functional limitations are usually a sign of reduced walking speed (Fritz, 2009) will contribute to the risk as well.

2.7 Stairs – Environment and Construction.

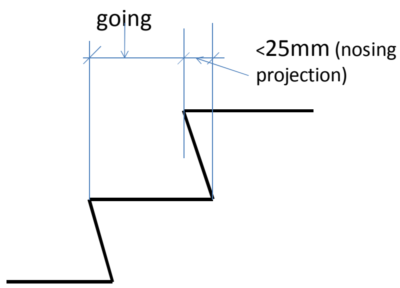
The literature sources for this section are from the fields of engineering science and occupational health and safety.

2.7.1 Stair geometry and pitch

Roys (2006) of the BRE determined that the most critical factor in stair descent was the width of the stair tread or going[61] as defined in - Figure 2-10 below:

[60] Distance to be travelled down the stairs is a direct function of building and storey height.

[61] Tread in this document is synonymous with going.



- Figure 2-10: Definition of Going and Nosing Projection

Roys (2006) showed that the minimum width should be 300mm to match the average length of the male foot. Pauls (1984) maintains that this could be reduced to 280mm to allow for a 25mm maximum overhang. These minimum dimensions allow the user to face front on when going down the stairs as a safeguard against falling.

A synopsis of stair geometry requirements is shown in Table 2-4. Pauls (1984) recommends a maximum 180mm riser for safe descent. Riener (2002) from the health science literature agrees with the range of slopes or pitches shown in Figure 2-11. Recent research in the UK shows that a slope or pitch between 18^0 and 23^0 results in a more user friendly stair for those with functional limitations including reduced vision (Alderson, 2010). NZ Compliance Document D1/AS1 (DBH, 2002) views this range as uncomfortable.

Country	Going	Riser	2R+G
Australia *(Building Code of Australia 2011 – Table D2-13)*	250mm min. 355mm max.	190mm max. 115mm min.	700 max (630 – 37^0) 510 min.(585 - 18^0)
New Zealand *(Approved Document D1 – New Zealand Building Code)*	255mm min. 375mm max	190mm max. 150mm min.	Max pitch - 37^0 Min pitch - 23^0
United Kingdom *(BS 5395-1:2010; Stair – Code of practice for the design of stairs with straight flights)*	300mm min 450mm max	180mm max 170mm for Approved Document M. 150mm min	600 min (31^0 max) 810 max (18.4^0 main)
United States *(Pauls, 2004 and Templer, 1992)*	280mm	175-180mm	(640 – 33^0)

Table 2-4 Stair geometry – international comparison (Stair pitch and the formula 2R+G are stated together – 2R+G is a measure of safe gait)

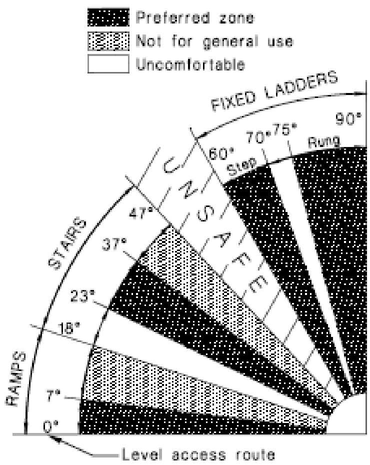


Chart from Section 1.2.1 of NZ Approved Document D1 - Access

Country	Comments
Australia	18^0-37^0
NZ	23^0 -37^0
UK	18.4^0-31^0
US	33^0

Australia and UK use entire range. US falls within range and NZ falls within nominated comfortable range. Roys (2006) would argue that goings should be a minimum of 300mm. Templer (1992) would argue that 280mm is adequate allowing for acceptable foot overhang.

Figure 2-11: Safe stair pitch and comparison table

Source Section 1.2.1 of N.Z. Approved Document D1/AS1 – Access.

Nagata (2006) shows that the individual never sees the entire tread when they go down the stairs. The visible part of the tread is T_N as shown in Figure 2-12 below. Based on Nagata's calculations (equation 7, Nagata, 2006) a tread of 300mm would be appropriate. This is important for stair conspicuity and foot placement.

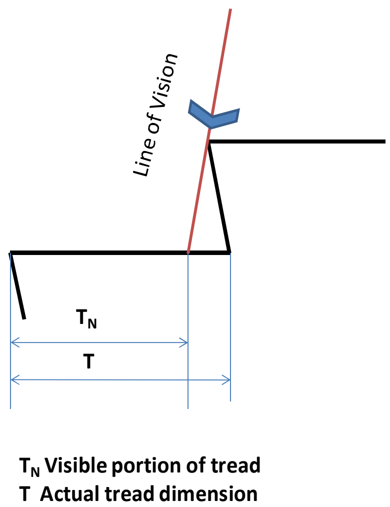


Figure 2-12: Line of Vision to the tread (Source: Nagata, 2006 Fig 2 – redrawn)

Combining this recommendation with that of Pauls (1984) for the maximum riser height, the resultant pitch would be 31^0, placing it within the preferred range referred to in Figure 2-11. A 150mm riser would result in a pitch of 26^0.

2.7.2 Step legibility

Figure 2-12 above shows the importance of foot placement but the steps need to be clearly defined by the marking of each nosing with a contrasting strip as now defined in BS 5395:2010 (BSI, 2010). It is noted that in order to provide for the safety of all individuals, especially those with reduced vision, that this requirement should be adopted for all exit stairs where regular trial evacuations are envisaged[62].

[62] Required under most Disability Discrimination and Health and Safety Acts in US, UK, and Australia.

2.7.3 Surrounding environment

Alderson (2010) and Archea et al (1979) advise on the importance of the following:

- Ensure a clear path of travel is available via flights and landings both in terms of visibility and actual physical presence
- Clear headroom throughout the path of travel (> 2000mm).
- Physical conditions within the stair that could distract the user e.g. viewing windows in terms of glare.
- Stair flights must be readily visible so that user can maintain focus.
- Stairs must be adequately illuminated. Care should be taken to avoid glare. Low level lighting may be used to define the steps and handrail.
- Handrails should available that are graspable preferably on each side of the flight.

The handrails should contrast with the walls (Alderson, 2010) and the colour of the walls should contrast with the stairs (Archea et al, 1979). This improves the conspicuity of all the safety elements as well as improving the orientation of the user.

2.7.4 Structural and dimensional integrity

The stairs should be free from vibration. Health science references (Horak, 2006) show that tactile feedback from a tread or unsteady handrail can affect an individual's stability.

Step geometry should also be uniform throughout each flight (Roys, 2006 and Pauls, 1984). Differences can trigger missteps (Templer, 1992 and

Archea et al, 1979). Codes permit between 5mm – 9mm[63] throughout the flight depending on the country involved. Roys (2006) and Cohen et al (2009) see uniformity as one of the most important requirements in stair safety due the mechanism of proprioceptive feedback.

2.7.5 Temperature and ventilation

All the Codes in US, UK and Australasia require some kind of provision to be made in enclosed stairwells in office buildings over 25m in height for smoke control/ ventilation[64]. This system should be designed in such a way so that air can be moved through the shaft either automatically or via manual means so as to cater for people who suffer from such diseases as Dyspnoea (breathlessness) or other cardiovascular problems and also to provide some relief from high temperatures (40^{0}C+) during trial evacuations such as could be the case in Adelaide (Australia) and Dubai (United Arab Emirates).

2.7.6 Signage and Symbols

According to Archea et al (1979) there is nothing worse than someone going down a set of stairs that come to either an abrupt end, a sudden change in level requiring them to ascend or to negotiate a winding changeover passage occurring between a high rise and a low rise portion of a multi-level office building. Proulx et al (2007) also reinforce this requirement through their findings from a trial evacuation case study where the level of illumination within the stairwell was reduced. Archea et al (1979) also advise that displaying level numbers on each main landing will improve the individual's orientation.

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[63] International Building Code (IBC) in US.

[64] E.g. Australian Standard 1668 Part 1, International Building Code (IBC) for Smoke Control.

2.7.7 Handrails and balustrades (guards)

Handrails provide a number of functions (Archea et al, 1979 and Templer, 1992):

- Guidance for those with impaired vision or for those with a fear of falling or lacking confidence with a prop.
- They provide an element at each landing involving change in direction about which the user can safely pivot.
- They provide extra support for those with low confidence or stability / vestibular problems or even those with musculo-skeletal conditions in their lower limbs.
- Handrails can act as a grab rail in event of a misstep so that the user can regain their balance using the handrail to create an opposing moment and force (Maki et al, 1998).

Alderson (2010), Roys (2006), Templer (1992) and Archea et al (1979) further advise that there are general issues to be observed with the construction of the handrail to fulfil its function. The handrail must be graspable (32-38mm) (ADA, 2002)[65] and at an appropriate height (e.g. 900mm). It must also be located at sufficient distance from the wall or other handrail when bounding an open void to permit the user's hand to wrap around it without any obstruction at any point. The wall behind the handrail must be smooth so as to avoid injury due to abrasion. The rail itself should be smooth, free from tactile knobs or splinters and should not be cold to the touch. The clearance between the walls and the inside of the rail should be greater than 50mm and preferably 60mm.

The minimum number of handrails required for stairs are normally governed by the width of stairs. The number is summarised in Table 2-5 below. The United Kingdom and the United States basically satisfy the requirements for

[65] Later edition has extended this range up to a 60mm diameter. New range can be challenged.

providing maximum opportunity to all sections of the population in terms of guidance and support. New Zealand only requires an extra handrail when the 'movement channel' exceeds 1499mm in overall width which is 1299mm clear width between handrails. Australia increases this width to 2m.

Country	Formula	Min.Width	Extra Exit	No. Handrails	Ht. Handrails
UK	$w = \frac{P + 15n - 15}{150 + 50n}$ Where P= no. of people:; (n) is no. of storeys; and W = width	1000mm	Two minimum and allow for one extra redundant on occasions	1<1000mm wide 2>1000mm wide	Between 900 and 1000mm
Australia	1000mm/100 people – this allows for the increase above 200 people. If >200 people then ≥ 2.0m	1000mm clear between handrails	Two minimum	1 < 2.0m 2 > 2.0m	865mm minimum
New Zealand	9mm per person	1000mm clear between walls or balustrades- can be reduced in certain instances	Two minimum do not have to allow for redundant if sprinklers installed. > 500 persons requires 3 exits	1 < 1500mm 2 > 1500mm Central handrail required when overall width > 2m and width of resultant channels < 1500mm	900mm min width
USA (allow same criteria for UAE	7.62mm per person unsprinklered and 5mm per person sprinklered.	1100mm between walls	Two minimum and allow for one extra redundant in special instances	Each side and 1 extra where greater than 1800mm	865-964mm

1. *UK Office of the Deputy Prime Minister (as at 2010) Approved Document B and K, The Building Regulations 2000*
2. *Australia – Australian Building Codes Board (2011), Building Code of Australia, Sections D1 and D2*
3. *New Zealand – Department of Building and Housing (as at 2011) Compliance Document C/AS1 and F4/AS1*
4. *United States and UAE – (Bukowski, 2009) and International Code Council (as at 2011) International Building Code and/or NFPA 5000*

Table 2-5: Stair widths and handrail requirements

All the Codes referred to in Table 2-5 require the handrails to be continuous from storey to storey but differ in their detailed requirements for graspability i.e. in terms of the minimum and maximum diameters. The optimum diameters of between 32 and 38mm (ADA, 2002) are the only ones discussed but other Codes allow up 50mm in diameter (Alderson, 2010).

According to Maki et al (1998) a handrail height of 900mm is suitable but where no balustrades are required in stairs this height may have to be increased when measured above the nosing line as the effective height can end up being less than 900mm. The UK allows a range of handrail heights between 900mm and 1000mm so that globally a height of 964mm should generally comply. This height can also be demonstrated to be satisfactory ergonomically using data from Pheasant and Haslegreave (2006). Pauls (1984) agrees with this finding. The critical height in terms of preventing falling through wide stair voids could be increased to 1200mm (MacLennan and Ormerod, 2011). Templer (1992) shows that steeper stairs affect people especially with narrow treads in terms of increased anxiety so that the presence of handrails and balustrades will increase the user's level of confidence (Reeves et al, 2008a and Maki et al 1998).

Where Codes such as BCA 2011 (ABCB, 2011) do not really cater for the risk of falling through open voids between flights this should still be addressed using a height of at 1100mm or even 1200mm which will cater for the measurement from an individual's base of support to their centre of mass (Pheasant and Haslegreave, 2006). All the Codes mentioned under Table 2-5 cater for balustrades including BCA 2011 in clause D2.16 (ABCB, 2011). Handrails should normally be circular and mounted within the balustrade line at the required height (Alderson, 2010).

2.7.8 Minimum width of stairs

The minimum width of stairs required by the Building Codes from the US, UK, Australasia and UAE are shown in Table 2-5 above. The minimum widths for almost all of the countries result in a clear width between handrails of between 900 and 1000mm. These minima were based on body sizes as they were over 40 years ago. Pauls et al (2007), Peacock et al, (2009) and Blair (2010) showed that these minimum widths were completely unsuitable for the increase in body size due to obesity.

Using the abdominal thickness of a morbidly obese individual it would be extremely difficult for anyone to pass this individual or a slow moving group as they would occupy staggered positions on each flight (MacLennan, 2008; Bukowski, 2009 and Pauls et al (2007). The same argument applies for any type of counter flow due to firefighting personnel. Analysis shows (MacLennan, 2011) that fire-fighters would be able to pass individual groups in a stair with a clear width between handrails of 1200mm. This is the minimum width recommended by Pauls et al, (2007). Fruin (Pauls et al, 2007) has recommended a width of 1520mm between walls which is 1320 mm clear between handrails.

The above discussion or assessment represents an ergonomic analysis as recommended by Pauls (2011), but it raises another issue of increasing the reach to two handrails to provide support for a person with musculo- skeletal pain in their lower limbs (e.g. osteoarthritis) and a vestibular disorder. Fruin's recommendations (Pauls et al, 2007) would still allow an individual to reach each handrail for support.

The minimum width of stairs is extremely important. A stair with 1320mm between handrails will permit individuals to pass the slow movers (Pauls et al, 2007) and reduce the stress that could occur as a result of "platooning" (Templer, 1992 and Parker-Pope, 2008).

2.7.9 Slip resistance

Slips on stairs are most common in descent accounting for up to 80% of all accidents (Cohen et al, 2009 and Reeves et al, 2008). A slip is most likely to occur when a person oversteps placing only 50-60% of their foot directly on to the tread (Roys, 2006). It is unlikely that this will happen with a going size[66] in excess of 300mm as this represents the length of a foot for the mean British Male (Roys, 2006 and MacLennan, 2011a).

Provisions need to be made to prevent slipping similar to those recommended in D1/AS1 (DBH, 2006) and BS5395-1:2010 (BSI, 2010). An equivalent coefficient of friction of 0.6[67] is recommended and would be achieved by most masonry materials as illustrated in a database for typical surface finishes and materials (DBH, 2006).

2.8 Management and maintenance.

Stairs and enclosed stairwells need to be maintained so that they are fit for purpose as originally designed. Improvements can be made in line with those described in Section 2.7. Evacuation drills should be held at least once per year in line with recommendations made by Averill et al (2005) and Gershon et al (2007) as a result of the WTC 9/11 incident and also as now required by Occupational Safety and Health Legislation in the US, UK and Australasia as described in 2.3.2.

2.8.1 The inclusive approach

Evacuation planning is all about planning for everyone so that an inclusive approach as suggested by Gwynne (2008) is advised where the individual and the potential 'group' are involved[68]. The procedures should be

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[66] A going of 300mm should increase the rate of descent because of better foot placement and increased confidence but distance is the main determing factor (Peacock et al, 2009)

[67] Equivalent to a Pendulum Test Value (PTV) of 40.

[68] In real life emergencies Zmud (2007) shows how a severely mobility impaired female person survived the WTC 9/11 incident due to this type of planning where a group of her colleagues

simple e.g. uncontrolled evacuation where people can enter into the stairwell when they are ready so as to avoid confusion. Staged or sequential evacuation that normally addresses fire related emergencies involve making PA announcements with instructions that people either cannot hear or understand (Proulx and Reid, 2006 and Kuligowski and Hoskins, 2010) will cause confusion. When this is coupled with lack of inclusive planning and planning as recommended in numerous guidelines (NFPA, 2007 and DCLG, 2007) then individuals will be confused and at risk especially where they should not be using the stairs at all (Proulx and Reid, 2006 and Kuligowski and Hoskins, 2010).

2.8.2 Emergency response planning and strategy

Emergency management involves the direct process of developing a plan, building and maintaining a strong emergency control organisation (transparent and inclusive), developing a set of procedures that includes a review step so that improvements can be made after each trial evacuation and the implementation of the process. Such an approach fits in well with quality assurance which underpins health and safety (MacLennan et al, 1999).

People will be more familiar with an emergency procedure if it refers to their normal use of the building and if they were involved in its development.

"People will trust a procedure that they understand and with which they are familiar."
(Gwynne, 2008, pp. 457).

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responded rapidly and took her to safety down the stairs in an "evacuation chair". Additional studies by Adams and Galea (2010) show that this device need not slow others down.

This section will not be concerned with the details of the policy and plans as these can be found in Codes such as AS 3745-2010 (Standards Australia, 2010). There are some issues, however, that need to be raised:

- Evacuation routes – it is quite common in some buildings to designate stairs for various levels. Whatever the approach is the user should negotiate the entire route as part of their evacuation training programme. (Gwynne, 2008).

- Central control – where evacuations are run from central control points these points may be blind i.e. they are not visually connected to the various floors or even the stairwell so that it is difficult for a central ECO to monitor all aspects of the evacuation or stair descent. This can impact on communication especially with sequential evacuation. Decentralisation of control to the floor evacuation teams should be considered. (Dwyer and Flynn, 2004).

- Floor evacuation teams that can motivate, lead and co-ordinate groups are essential for each tenant in high rise office buildings. These groups need to reflect the decisions of the occupants on each floor and have standard plans to cater for visitors (assign to groups). The rapid response of major tenants in the WTC9/11 Incident is an example of this (Dwyer and Flynn, 2004).

- Training and practice – at least one drill should be conducted per annum that involve moving though the exit system. Practice should also involve the development of skills such as that required for assisting others, operation of evacuation chairs as evidenced by the Adams and Galea study (2011) and Zmud (2007).

- All plans should include inspection and maintenance of all essential services and this includes the elevators and the stairwells. There are Codes and Standards that cover this aspect. (Beck, 1977)

The above requirements reflect the basic requirements of AS 3745-2010 (Standards Australia, 2010) which is also representative of the NZ requirements as well as those of the US and UK.

2.8.3 Maintenance

All essential services, i.e. those to do with life safety need to be inspected, tested and maintained to ensure that continue to be fit for purpose over the life of the building (e.g. requirements under BCA 2011 (ABCB, 2011)). This requirement refers especially to illumination, ventilation and stair condition in studies over the last three decades commencing with Beck (1977). Many high rise office buildings in the modern era were designed using specific design methods permitted under various building regulations (e.g. BCA 2011 (ABCB, 2011)). Inspection, test and maintenance protocols may vary from those in the Codes so that they should be documented using a combination of quality assurance and maintenance Codes that are already available (e.g. AS 3900 and AS1851). An example of this is the proper functioning of the stairwell ventilation systems and not their failure as will be seen in the 2008-2010 Case Study forming part of the PhD Study (Building M2).

2.9 Synthesis of the Literature review and development of the knowledge gap.

Chapter 2 is synthesised over page in using the Ishikawa Chart (RCA Model[69]). This model as will be demonstrated in this section is based directly on the Functional Capacity Evaluation Model (Matheson, 2003) as explained in

[69] Portwood and Reising (2007) describe the basis of Root Cause Analysis Models which utilise Ishikawa Charts which are synonymous with Quality Management Methods commonly used in Health and Safety Management

section 2.9.1. The outcome of the evaluation of an occupant's functional capacity to safely complete a trial evacuation will relate directly to their ability to go down stairs without falling. The evaluation may show that the impact of the specific extrinsic factors associated with the building, the stairs, the other occupants and the way in which evacuations are managed require an alternative strategy for the occupant being evaluated. The RCA model[69] therefore needs to be flexible so that it can be used inclusively[70]. The model and synthesis is shown in Figure 2-13 and elaborated on further in this section.

Figure 2-13 is an Ishikawa Chart also known as a "Fishbone" diagram (Battino, 2006) summarises the contextual issues under four main classifications[71] located on the "fins" of the chart determined from the literature review. The spine represents outcomes from the interaction of the contextual issues on the level of performance or the functional capacity of the individual descending the stairs in terms of the maximum distance they estimate they can travel before running the risk of falling or sustaining some other threatening medical condition (e.g. heart attack). The knowledge gap[72] is therefore:

- Which of the contextual issues are critical in determining the level of performance of the individual descending the stairs?
- The level of performance or functional capacity determined in the above context utilising a combination of survey and observational tools where fitness has been measured using a validated method (Sjostrom et al, 2005) and where the data can be triangulated.

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[70] As a template for developing occupant Personalised Emergency Evacuation Schemes.

[71] Determined by the Delphi group forming part of the 2008-2010 case study.

[72] Highlighted red-brown in Figure 2-13

When the level of performance or functional ability of the individual is matched with challenges of the building and the proposed evacuation strategy it will be possible to determine whether or not the individual concerned can either use the stairs safely or requires assistance.

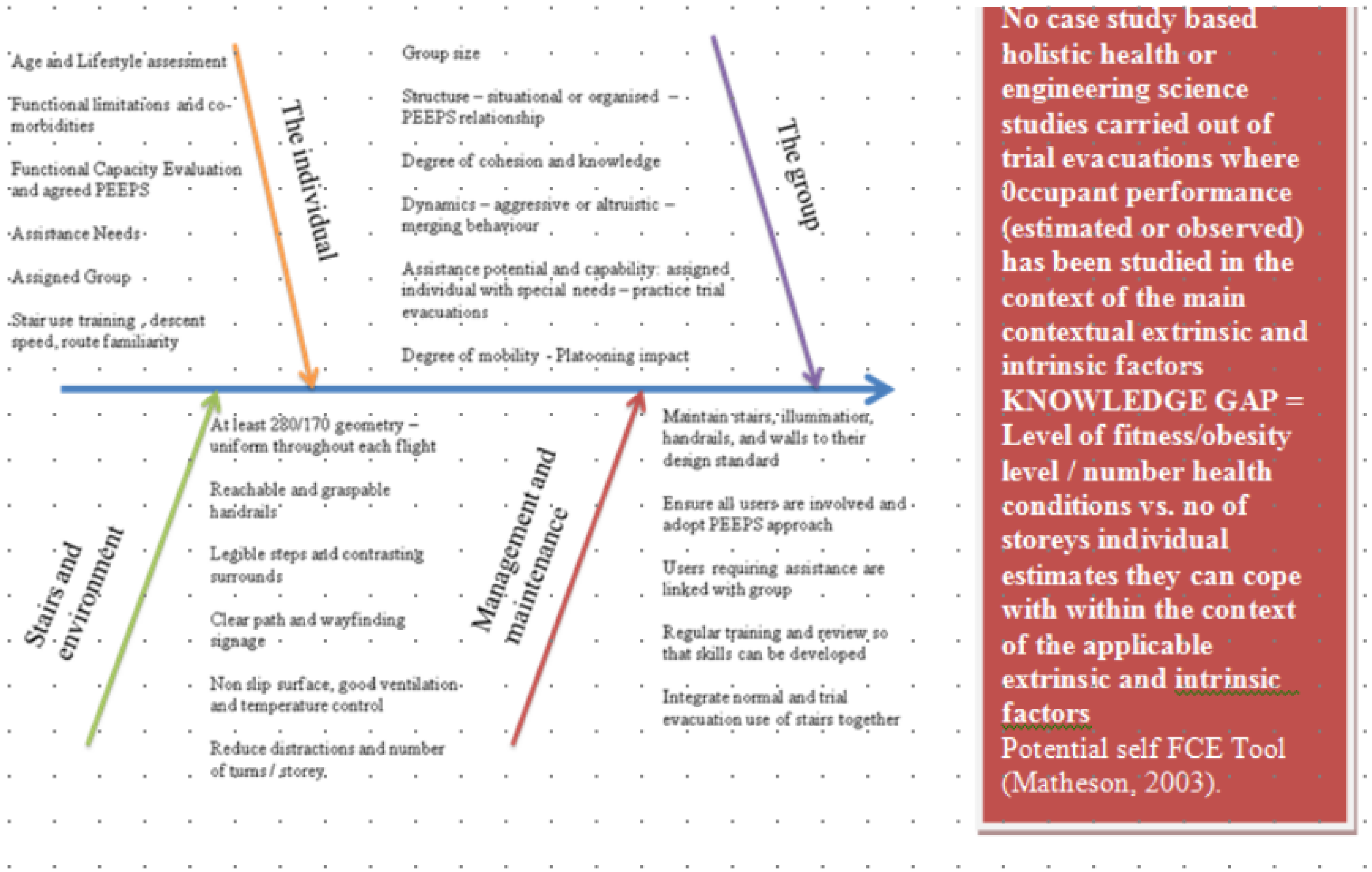

Figure 2-13: Summary of literature review that establishes the knowledge gap *(See section 2.9.1 – 2.9.5 tying explanation of the above to sections 2.1 and 2.3 – 2.7*

2.9.1 Derivation of the Root Cause Analysis Model

The basis of the Root Cause Analysis (RCA) Model used in this PhD Study is based directly on Health and Safety practice and systems as described by Portwood and Reising (2007) drawing from the FCE Model of Matheson (2003). The FCE Model is used as a tool to evaluate the functional capacity of an employee or individual. It is unsuitable for inclusive evaluation[73]. The RCA Model in the form of the Ishikawa Chart[74] allows for direct employee or individual input.

Referring to Figure 2-1 the translation of the FCE Model into the RCA Model can be best described as follows:

- The occupational disability is presented as the outcome of the interaction of all the contextual extrinsic factors on the individual's particular intrinsic characteristics and is measured as the maximum distance a person can descend without a rest or where the risk of falling is too great.
- Individual impairment translated into functional limitations is presented as the Intrinsic Factor related to the individual being studied.
- Worker role demands are presented as the particular demands associated with the particular building being the characteristics of the stair construction and environment, the group comprising the individual and others on the stairs at the same time and the building emergency evacuation organisation, strategy, planning and procedures. The

[73] RCA Model allows participation and is widely used in health and safety planning (Portwood and Reising, 2007). It permits participation of the individual (bottom up) together with the evacuation planner (top down). The FCE Model is basically a "top down" approach. Evacuation planning needs to be inclusive as demonstrated by Zmud (2007) and Gwynne (2008).

[74] As described in Battino (2006) where it is linked directly with RCA.

demands therefore comprise the specific extrinsic factors associated with each building.

2.9.2 The Intrinsic Factor (Individual)

The results of the literature search addressing the intrinsic contextual factors and which would comprise the individual characteristics and functional abilities of an individual are summarised as:

- Age and lifestyle where lifestyle refers to the degree of sedenterism[10] and therefore physical activity. Age is usually coupled with this taking into account other changes such as loss of strength and increases in the level of obesity.(Section 2.4)
- Functional limitations usually directly associated with various impairments some of which are not necessarily defined as disabilities. Cardio vascular, neurological, musculo-skeletal conditions are amongst those considered and discussed in Sections 2.4 and 2.5.
- Co-morbidities such as cardiovascular and diabetes are discussed where the conditions are linked. Reduced vision and Type 2 Diabetes are another example. Other examples are obesity and hypertension. As the number of co-morbidities increases so does their impact on stair descent ability. (Sections 2.5).
- Individuals as employees have the legal right internationally to be provided with a safe work place.
- Functional Capacity Evaluation (FCE) needs to be carried out inclusively using the PEEPS[44] approach so that the demands of the stairs, work colleagues and management can be integrated with the needs and functional limitations of the individual. (Section 2.4)

- If the individual has the functional ability to descend the stairs then familiarisation with the specific extrinsic factors where measures similar to the 6 minute walking test (Ayis et al, 2007) can be used. This will provide actual performance results especially in terms of the maximum distance that can be safely descended. (Section 2.4)

- Section 2.5 shows up a negative aspect of group dynamics related to individual behaviour where an individual inadvertently descends at an uncomfortable speed, being the speed of the group> this increases the risk of falling especially where the individual has more than one co-morbidity (Section 2.5).

- Assistance needs can be established from the FCE.

The RCA / FCE method can therefore be used as a research, evaluation, training and monitoring tool for the individual and should therefore be inclusive.

2.9.3 Others on the stairs – The Group.

The results of the literature search addressing the interaction of the individual with others on the stairs are summarised as an extrinsic factor:

- Groups are formed in trial evacuations either by the occupants themselves or as a result of the evacuation strategy. The groups will vary in size.
- The structure, dynamics and behaviour of each group will depend on the degree of occupant inclusion and motivation. It may often be situational.
- The degree of cohesion and knowledge will depend on the frequency of training or practice.

- It is possible that group behaviour which is usually altruistic may be aggressive. Aggressive behaviour is usually minimal and will be addressed in the research although not directly addressed in the literature search[75]. Also accounts for variability in merging patterns.
- The group will most likely help an individual in need but there may be a risk in doing so especially where the individual is morbidly obese or injured as the result of a fall. Group formation should therefore address the needs and functional limitations of all the members. The degree of mobility and strength of the individual is important because slow movers can impact other following groups as well especially in terms of "platooning" making it difficult for others to pass.
- Practice is essential to evaluate results of Individual FCE in a group setting
  (*Refer to Section 2.6 for the above*)

Lack of group practice may result in members being too embarrassed to ask the group to slow down and therefore increase the risk of falling due to the loss of focus and visibility due to "rushing".

2.9.4 The stairs (construction) and their environment – extrinsic factor

The results of the literature search addressing the construction of the stairs and the enclosing environment are summarised as an extrinsic factor:

- Optimum tread and riser sizes which are uniform throughout.
- Handrails need to be reachable and graspable.
- Stairs need to be conspicuous for ease of foot placement and to increase confidence.

[75] Discussed briefly in Section 2.5.3 (Pauls, 2004) as a lack of courtesy.

- Clear path to avoid obstacles that could trip the user and signage for orientation and wayfinidng.
- Non-slip surfaces, temperature and ventilation control.
- Minimum width of stairs (>1200mm) to allow for counter flow, overtaking and resting.
- Distance to be traversed combined with number of turns per storey is important because of the impact on fatigue and the increased risk of falling. There is a maximum distance between rests where they are provided as exemplified by the 60 minute walk test and the reduction in descent speed[76]
- Distractions need to be reduced to deal with risk due to loss of user focus.

Distance may quite well alter user perceptions of what constitutes a comfortable and safe stair due to user fatigue and other functional limitations.

2.9.5 Management and Maintenance – extrinsic factors

The results of the literature search addressing the maintenance and management of the stairs and evacuation system as an extrinsic factor are:

- Lack of maintenance can result in the deterioration of the stairs and their environment so that they are no longer "fit for purpose".
- Evacuation procedures need to be simple and inclusive. Staged evacuation can increase confusion. They can also decrease the density and increase descent speed highlighting the risk of falling. Uncontrolled evacuations increase density and decrease descent speed so users have more time to rest.

[76] Maximum distance as per Ayis et al (2007) and correlation of descent speed with distance as per Peacock et al (2009).

- Inclusive planning modelled on FCE involves the user and obtains their “buy in” for all aspects of trial evacuation performance and assistance.
- Group assistance skills are developed as part of trial evacuation exercises.
- Legal obligation is fulfilled inclusively.

The WTC 9/11 incident showed the value of committed evacuation management where organisations (management and employees) were committed to and familiar with procedures that suited their needs and were quick to respond. Everyone knew what they had to do.

2.9.6 The Knowledge Gap

The outcome of the FCE Model (Matheson 2003) is stated as “occupational disability” which establishes the performance level or functional ability of the individual in the context of the task, the working environment, the staff, resources and management. Peacock et al (2009 and 2012) carried out a similar study but this did not consider all the contextual factors. A number of buildings were studied and a multivariate analysis of aggregated data revealed that distance was the most significant predictor of speed (see Figure 2-14 and in particular the items highlighted or edged in red). Fritz (2009) in his seminal paper on functional limitations clearly shows up walking speed as a predictor of functional ability. Boyce et al (1999) relates walking speeds to functional ability. Leake et al (1991) in a study of pedestrians with impairments resulting in varying functional abilities related distance to functional ability. Ayis et al (2007) develop the notion of maximum distance that an individual can cover before having to sit down and rest. Spearpoint and MacLennan (2012) describe this relationship as an individual’s functional capacity. The latter could also be seen as a level of performance i.e. **the maximum number of storeys an individual could descend without a rest.**

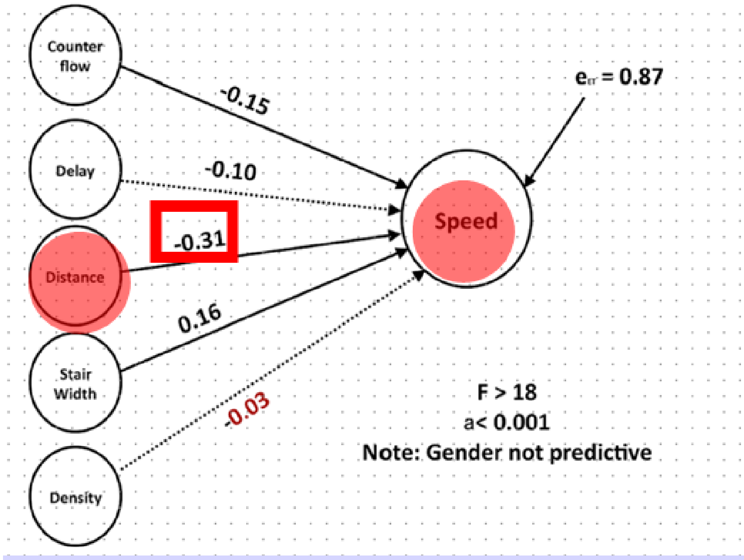

Figure 2-14: Relationship between distance and speed.

(Source: Peacock et al (2009) Read in conjunction with Figure 2.3 from Ayis et al (2007) which shows the maximum distance that can be walked related to an individual's functional limitations. Maximum distance therefore represents the individual's functional ability or performance level. Also note that the impact of counter-flow on descent speed depends directly on the Fire Department's Standard Operating Procedures which can utilise emergency lifts for fire fighter access (MFB, 2010).

Maximum distance or maximum number of storeys could be taken as either an estimated or accomplished limit. It also represents "occupational disability" from the FCE Model (Matheson, 2003). The literature survey shows that the FCE Model or similar has not been applied to trial evacuations as an occupational task.

The RCA Model (Portwood and Reising, 2007) using the Ishikawa Chart as the framework illustrates the knowledge gap. The knowledge gap is summarised by the Aim and Objectives in that estimated or actual descent ability (as represented by the number of storeys traversed) is to be studied in the context of the extrinsic and intrinsic factors to establish which factors or combination of factors affect the number of storeys that can be descended without a rest. The studies in this review show that maximum distance or number of storeys, if taken to represent the level of individual performance, will be mostly affected by the level of fitness, number of functional limitations (co-morbidities) and level of obesity subject to the demands of the other intrinsic and extrinsic contextual factors.

Whereas most of the earlier engineering science studies (Fruin, 1987 and Francis and Saunders 1979) viewed the individual as an object, later studies focussed more on the individual as a human being with distinct and variable characteristics that affected their performance mirrored in studies carried out by Boyce et al (1999) and Fahy and Proulx (2001). These studies highlighted the difference in descent speeds are a direct outcome of their functional limitations. This agrees with similar health science studies (Fritz, 2009 and Hulens et al, 2003). Proulx and Reid, (2006) showed up the impact of behaviour and delays resulting from conflicting messages generated by an evacuation communication system in a fire related emergency. Kinsey et al (2010) studied the individual in relation to the use of escalators for evacuation. The process used by Kinsey et al (2010) determined a similar maximum performance stair descent measure based on the distance an individual estimated they could safely descend. The RCA Model Spine outcome also includes an estimated measure which can be compared with the results of the author's unpublished 1980's research and that of Kinsey et al (2010)[77]. The studies now focus on the individual and therefore the individual should be the centre "unit of analysis" within specific contexts.

[77] Also provides the opportunity for a longitudinal study as the level of performance of 50% of the population in the 1980's generalised between eight buildings was 25 storeys and the 2010 study by Kinsey et al (2010) was 21. The latter was established by survey whereas the one established as part of the 2008-2010 case study will be one generalised between 6 buildings utilising a case study process outlined and justified in Chapter 3.

2.10 Summary and Conclusion

The research philosophy, strategy and method therefore follow on in Chapter 3 with the description of the case study sites following on in Chapter 4. The method approach is unique to this PhD Study needs to be one particularly suited to real world studies when compared to other trial evacuation studies (Proulx et al, 2007: Pauls, 1977; Beck 1977; and Peacock et al, 2009) in that it allows for the inclusion of the Author's unpublished research conducted in the 1980's as an exploratory case study which results in the entire PhD Study taking on a longitudinal profile for a more meaningful analysis of the Pauls, Fruin and Zupan (2007) claim that population fitness has deteriorated in the last 30 years along with the masking of fatigue by density found by Galea et al (2008) in one of their studies of the WTC 9/11 incident.

Chapter 3: Research Philosophy and Methodology

3.1 Introduction

Pauls, Fruin and Zupan (2007) claim that that their trial evacuation data are no longer relevant. The claim is concerned with the intrinsic characteristics of the current population and their fitness when compared with those of the population in the 1970's. Pauls (1974) collected data from trial evacuations of office buildings in Canada and Fruin (1987) from observations of people moving around public places in New York and elsewhere. Pauls (1974) developed data collection methods that were a combination of survey and progressive observation of survey respondents for the duration of the evacuation. Observations were made by researchers moving down the stairs with the survey respondents and also using video cameras at strategic points. At that time Pauls (1974) carried out the research for the National Research Council of Canada (NRCC). A form of triangulation[78] was used to compare the data. This approach is synonymous with use of "mixed methods" or the pluralist approach in data collection and analytical methods (Amaratunga et al, 2002). The author together with Pauls and two other international experts[79] advanced the original 1970 studies under a grant from the Australian Uniform Building Regulations Co-ordinating Council commencing in 1983 using a slightly more structured approach. The resultant data is partly published (MacLennan, 1989, and MacLennan et al, 1999)[80]. The data still exists and therefore offers the opportunity for some kind of longitudinal study associated with the aim of this PhD Thesis.

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[78] Triangulation as defined and discussed by Hales (2010)

[79] Jake Pauls, Edwina Juillett and Dr. J.D.Sime

[80] The research project was terminated prior to completion due to lack of resources and funding.

In line with the above opportunities this chapter is concerned with establishing the most appropriate research philosophy and then a method that will fit within this philosophy. This potential is from the position that the author's 1980 work was in sync with the data referred to by Pauls (1988)[81] as well as that used to date by the same organisation that supported the initial work of Pauls which was the National Research Council of Canada (Proulx et al, 2007).. The details and protocols of this PhD study will therefore be described in terms of the project being a real world study and will then refer to the other trial evacuation studies (Pauls, 1988 and Proulx et al, 2007) in terms of process, data gathering and analysis.

3.2 Research Philosophy

According to Gray (2009) and Crotty (1998) there is an inter relationship between the theoretical stance adopted by the researcher and the methods used. Miles and Hubermann (1994) show that there are three underlying assumptions relevant to research philosophies being:

- Ontological assumptions
- Epistemological assumptions
- Axiological assumptions

Ontology describes "what knowledge and in fact reality is[82]" whilst epistemology relates to the meaning of knowledge and how it should be acquired and accepted. Axiological assumptions also play a role as they reveal the values researchers place on certain things and therefore their value systems (Miles and Hubermann, 1994). Gray (2009) states further that any philosophy, strategy and method would normally be influenced by both what it means to know and their values.

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[81] Pauls (1988) refers to the author's work and acknowledges the association of this work with his especially in terms of the data collection methods.

[82] E.g. the truth

The author used the research onion (Saunders, 2007) to determine his research philosophy and strategy.

The author is investigating the performance of individuals descending multiple flights of stairs within context. One study of the WTC 9/11 incident (Galea et al, 2008) shows that fatigue may not be an issue in stair descent and yet other health science studies do (Corbeil et al, 2001). Another study by Peacock et al (2009) shows that the distance traversed has the most marked influence on descent speed. Blair (2010) using data from this same study states that the data is extremely "noisy" i.e. there are many other data not being gathered or interrogated. Ayis et al (2007) indirectly supports Peacock et al (2009) in showing that fatigue is a function of reduced walking speed and hence distance. Galea et al (2011) does submit that fatigue may not show up because it is masked by density. There are potential rival theories (Yin, 2009) about what the truth really is in this regard. This is one of the reasons for the author adopting a particular epistemological stance in this instance. He sees that meaning or relationships can be ambiguous or even uncertain. It is therefore necessary to understand the context in which these issues exist or occur (Gray, 2009). There is a need to construct this meaning for it to be "real" (Saunders, 2007 and Gray, 2009).

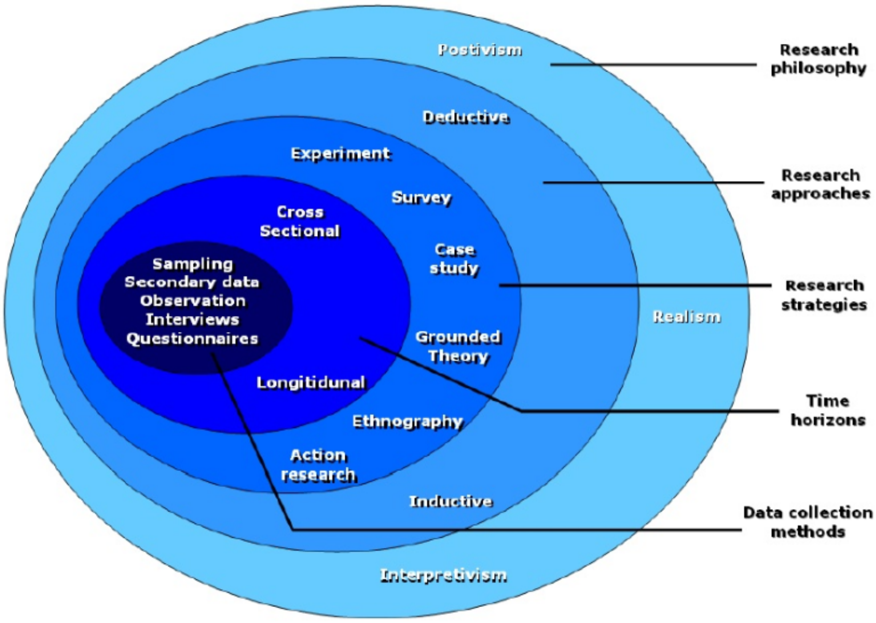

Figure 3- 1: The Research Onion (Saunders et al, 2007)

Figure 3- 1 shows the various layers of Research Methods. The author in adopting an epistemological stance as a constructivist may be seen as a direct conflict of paradigms. This is not the case and in fact the two are compatible and yet distinct (Barkin, 2003). The stance selected is not positivist as the theories do not allow for the study of specific social issues which are critical to this PhD Study (Saunders 2007). Interpretivism is more applicable as a stance as it would allow the author to focus on the social issues. This unique approach however does not permit generalisability between within the context of other cases or research. Constructivism linked with realism (Barkin 2003) is a theory which holds the social phenomena and their meanings are constructed by the people in using them rather than being external objects existing independently of them.

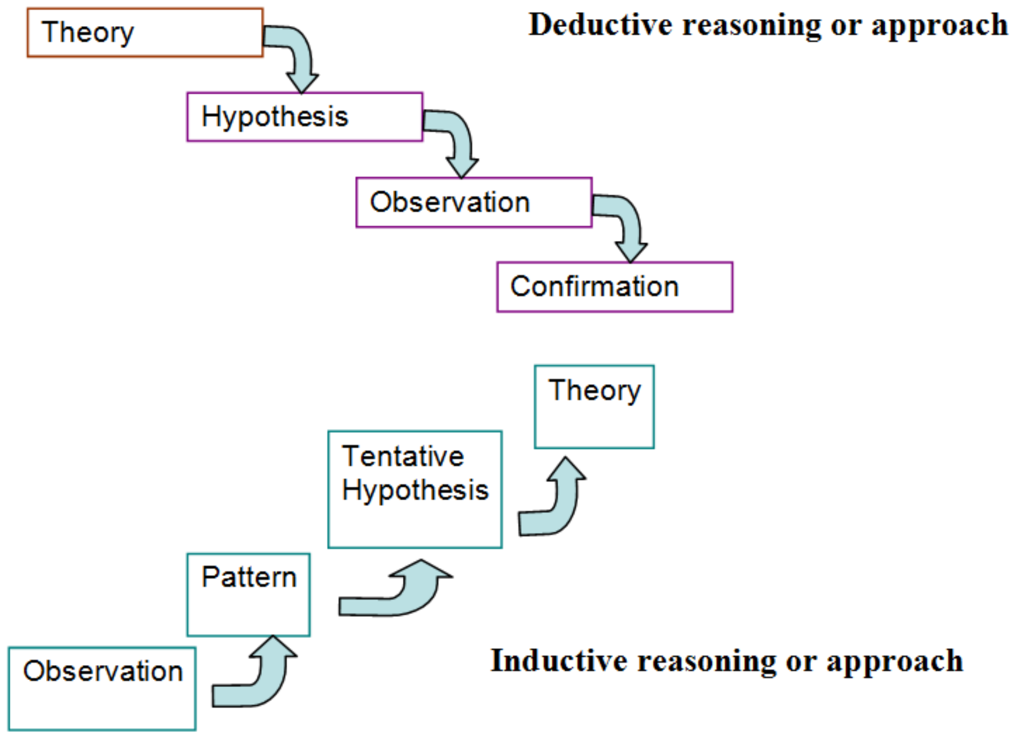

Figure 3- 2: Research Approach: Deductive vs. Inductive – (Source: Spratt et al, 2004)

Peeling away the next layer of the Research Onion (Saunders et al, 2007) requires the approach to be employed in the research study. There are two approaches available being *Deductive* and *Inductive* (see Figure 3- 2). Deductive is known as a top-down approach going from the general to the particular. It starts with a theory about the topic of interest (multiple flight stair descent) which is then narrowed down to a more specific hypothesis (individual performance in stair descent) which we can test. This approach most likely involves quantitative methods. The Inductive approach works in the opposite direction as shown in Figure 3- 2 and works from the specific to the general where an empirical observation takes the researcher to a result. It allows for generalisation and is informally known as the bottom-up approach. Qualitative methods are normally associated with this approach (Gray, 2009).

The next layer of the onion is the research strategy (Saunders et al, 2007). The author's position here is strongly influenced by the "inherent" strategy followed in his 1980 trial evacuation studies introduced in Chapter 1. The data collection methods from this study involved the use of interviews, survey and observation. This involves the use of mixed methods (Amaratunga, et al, 2002). As such triangulation between data sets (Hales, 2010) is critical for arriving at a theory that can be generalised. It also reflects a mixture of research approaches (deductive and inductive) and matches the author's epistemological stance as explained above.

The aim of the PhD Study is;

"***"To study the performance of mature age office workers descending multiple flights of stairs in trial evacuations of high rise office buildings in the context of extrinsic and intrinsic factors".***

The PhD Study involves the study of office workers within the context of trial evacuations which means that the identification of contextual issues is extremely important especially as far as generalising theories and/or findings are concerned. Amaratunga et al (2002) recommends a mixed method strategy for studies concerning the Built Environment. The most suitable mixed method or "pluralist" strategy is case study. It is defined as the study of a social unit where the centre of the study is normally a person, group or social institution. The PhD Study aim aligns itself with the case study approach as it studies context in detail (Yin, 2009). The important attribute of case studies is that they can be used for generalisation but only when there is a distinct pattern (Hak and Dul, 2007) set up between outcomes.

The case study method is ideal when asking "how" or "why" question about a set of events over which the researcher has no control. The original trial evacuation studies by Pauls (1974) allowed for some control when examining the data collection methods[83]. This was not the case with the author's 1980 study[84] and the PhD Study described in this thesis. The case study is an accepted method within itself and for this method to be successful it has been designed in accordance with one of the authorities on Case Studies (Yin, 2009) as acknowledged by Gray (2009). The design of the case study process for the PhD Study is discussed in the next section. It will be a multiple case study process holistically known as the "**PhD Case Study**".

The author's position in terms of philosophy, approach and strategy is explained in Figure 3-3 where he occupies a central position from epistemology through to data collection methods and where the overall process is designed as a case study that allows for both a top-down and a bottom-up approach which involves the individual as the central unit of analysis. This reflects other studies by Gershon et al (2007) on the WTC 9/11 incident and also the inclusive approach to evacuation planning (Gwynne, 2008).

[83] In the 1970 NRCC trial evacuation studies observers lead and followed groups of evacuees down the stairs and therefore may have influenced or even controlled the rate and pattern of descent. In this PhD Study this is not the case so that the author and his observers had no control whatsoever over the evacuation events.

[84] As introduced in Chapter 1.

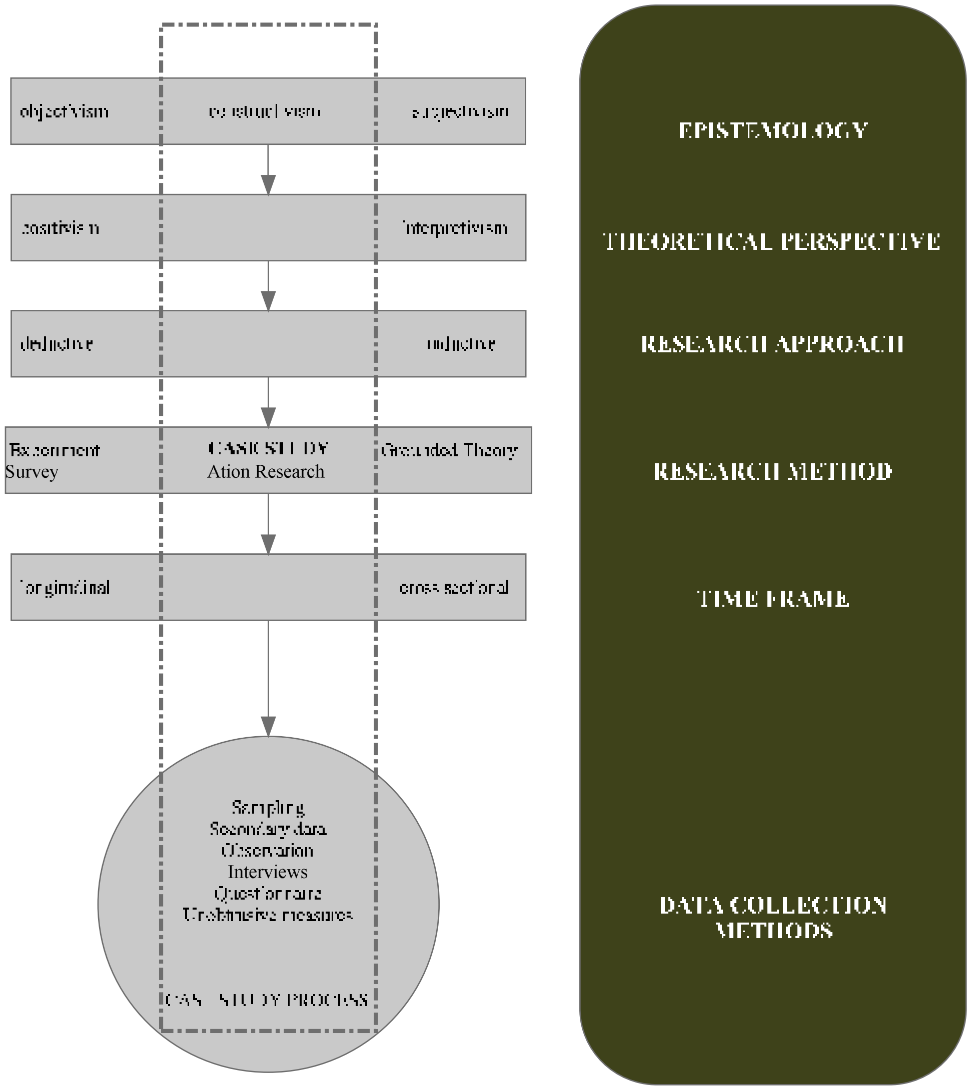

Figure 3-3: The Elements of the Research Process used in the PhD Study using Gray's (2009) "peeling" of the Research Onion (Saunders et al, 2007)

3.3 The Case Study Research Strategy

3.3.1 Overview

As discussed in the previous section the case study strategy has been selected as the research strategy as it permits the use of mixed methods, has a central unit of analysis being the individual and studies their performance in descending stairs in trial evacuations in the detailed context of different buildings, populations and management structures/ practices. The context is made up of intrinsic and extrinsic factors which are identified as part of the contextual aspect of the multiple case study. Chapter 2 showed that these factors would most likely be:

- The individual office worker
- The individual and others – group
- The design and construction of the stairs
- Management and Maintenance

The selection of the case study method will allow for the same mix of data collection methods to be used as the author's 1980 study (Box 2 - Figure 3-4) so that a form of longitudinal study[85] is possible because of the commonality of methods.

[85] i.e. between cases where time horizon represents the interconnection and comparison of cases and generalisations.

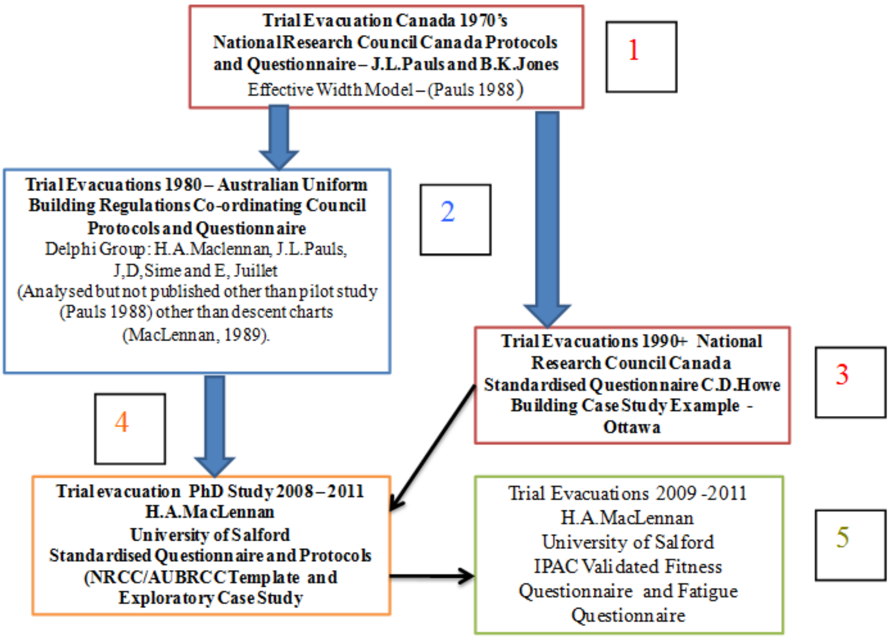

Figure 3-4: Setting the replication of research method and data collection/ analysis by the selection of cases and the time span of study

Figure 3-4 shows the linkage between the 1970 NRCC studies (Box 1), the author's 1980 study (Box 2) based directly on the NRCC studies providing the opportunity and set data for the Exploratory case study (Box 4) for the PhD Study. The NRCC continued on with trial evacuation studies, the seminal one being the "C.D.Howe" building in Ottawa, Canada (Proulx et al, 2006) as shown in Box 3. The data collection methods used in this study was similar to that used in Box 1. The Exploratory case study then links in with what is known as the current or 2008-2010 case study (Box 5). In order to allow for the case structures to be similar and so that longitudinal comparisons could be made the data collection methods directly connected with the 2008-2010 trial evacuations were kept in sync with the others.

The robustness of the Case Study method could still be challenged especially in terms of the estimated conflict between quantitative (positivist) and qualitative (phenomenological) methods. According to Amaratunga et al (2002) existing built environment research which in terms of this PhD Study would include quantitative studies of Peacock et al (2009) and qualitative studies such as those by Gershon et al (2008) may involve the use of mixed methods which is represented in Figure 3-3 in the positioning of the linking arrows between the elements of the research process as defined by Gray (2004). Amaratunga et al (2002), argue from a philosophical point of view that there are two schools of thought being logical positivism which relies on quantitative methods to test hypothetical generalisations. Here the observer is required to be independent from the subjects being observed. Phenomenological or interpretivism inquiry uses qualitative and naturalistic approaches to gain an overall understanding of human experience. A pluralist approach is therefore perhaps the most realistic way to "interpret" outcomes. Amartunga et al (2002) refer to another study carried out by Das (1983) where he states that:

"…qualitative and quantitative methodologies are not antithetic or divergent; rather they focus on the different dimensions of the same phenomenon. Sometimes these dimensions may appear to be confluent: but even in these instances where they apparently diverge, the underlying unity may become visible on deeper penetration….The situational contingencies and objectives of the researcher would play a decisive role in the design and execution of the study."

Amaratunga et al (2002) appear to view the "deeper penetration" as an emphasis on the use of triangulation (Hales, 2010) which is a "collective' method that combines quantitative and qualitative analytical methods. Yin (2009) sees this triangulation as being the way of overcoming the weaknesses in each method. It allows for a bridging of the positivist and phenomenological stances via the case study method as indicated in Figure 3-3 and justified against further criticism by Flybjerg (2008) in Table 3- 1. Yin (2009) does still support a balance between the two methods and this is seen as being ideal. The pluralist or mixed research method therefore still permits the researcher to become immersed in their own research (Amaratunga et al, 2002). Rossman and Wilson (1991) as cited in Amaratunga et al, (2002) provide further reasons for linking the two methods of analysis:

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- To enable confirmation of each other via triangulation;
- To elaborate or develop analysis, providing richer details; and
- To initiate new lines of thinking through attention to surprises or paradoxes providing fresh insights. ″

Amaratunga et al (2002) also see case study research as one that focuses on the "dynamics" within single settings. In the case of high rise building stair descent research the single setting is the enclosed stairwell or fire stair. The setting in this instance is affected by other dynamics made up of intrinsic and extrinsic factors. The unit being analysed in still the occupant or individual descending the stairs so that mixed research methods used to both gather and analyse data need to be balanced so that triangulation is possible. The case study process needs to be designed in order for the misunderstandings in case study methodology to be explained as they are in Table 3- 1.

MISUNDERSTANDINGS	EXPLANATION (Flybjerg, 2006)
General theoretical (context independent) knowledge is more valuable than concrete (context dependent) knowledge.	Predictive theories and universals cannot be found in the study of human affairs. Concrete context dependent knowledge is therefore more valuable than the vain search for predictive theory and universals
One cannot generalise on the basis of an individual case, therefore the case study cannot contribute to scientific development	One can often generalise on the basis of a single case and the case study may be central to scientific development via generalisation as supplement or alternative to other methods , Formal generalisation is over-valued as a source of scientific development, whereas the force of an example is underestimated
The case study is most useful for generating hypotheses; that is, in the first stage of a total research process. Whereas other methods are more suitable for hypotheses testing and theory building	The case study is useful for both the generating and testing of hypothesis but is not limited to these research activities alone
The case study contains a bias towards verification, that is, a tendency to confirm the researcher's preconceived notions	The case study contains no greater bias towards verification of the researcher's preconceived notions than other methods of inquiry, On the contrary, experience indicates that the case study contains a greater bias towards falsification of preconceived notions than towards verification
It is often difficult to summarise and develop general propositions and theories on the basis of specific use case studies	It is correct that summarising case studies is often difficult especially as concerns case process. It is less correct as regards case outcomes. The problems in summarising case studies, however, are due more often to the properties of the reality studied than to the case study as a research method. Often it is not desirable to summarise and generalise case studies. Good studies should be read as narratives in their entirety.

Table 3- 1: Explanation of the misunderstandings of case studies as a research method (Flybjerg, 2008)

3.3.2 Case Study Process Design

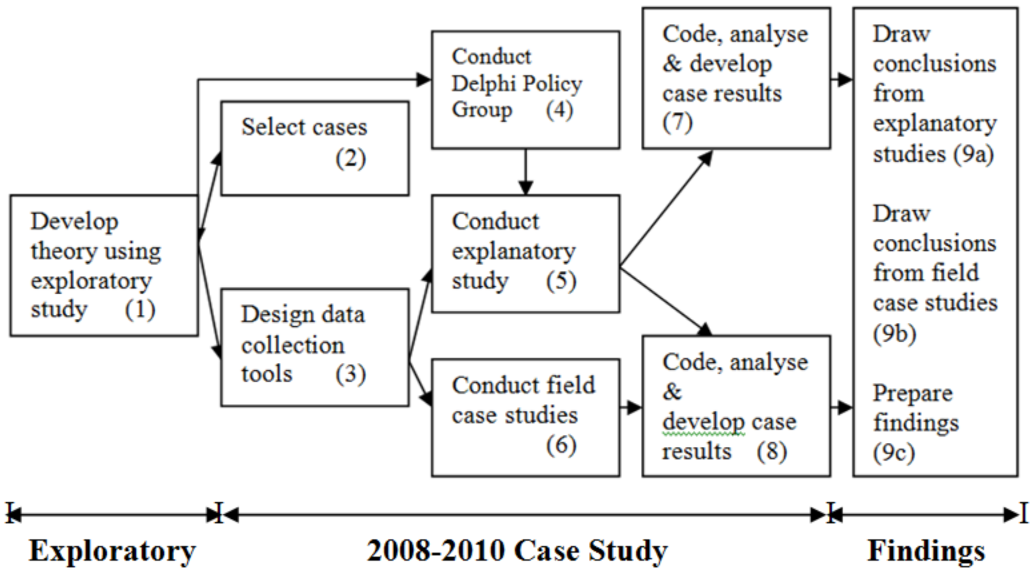

Figure 3- 5: Generic PhD case study process chart

Using Figure 3- 5 as the reference, the types of case studies that may be included in a case study process where the case study is a multiple case study (Gray, 2009) are as follows:

- Exploratory case studies (Box 1)
- Explanatory case studies (Boxes 4 and 5)
- Confirmatory case studies (Box 6)

The generic case study process in Figure 3- 5 is based directly on Yin (2009). Yin permits the use of the above study types where:

- The exploratory case study which is a re-analysis of some of the data from the author's 1980 study is to be used to develop the theory for the 2008-2010 case study as well as two of the buildings from the 1980 study which will be representative of the eight buildings studied and which will be known as the exemplar buildings and will be included for further detailed comparison in the 2008-2010 case study. (Box 1)

- Explanatory case studies to further explain the results of the 2008-2010 trial evacuation studies. The Explanatory case studies comprise a Delphi group[86] to establish the context of the 2008-2010 case study, focus group studies to compare intrinsic characteristics[87] of young and fit office workers with mature and unfit office workers and content analysis of two documents Dwyer and Flynn, 2004[88] and Parker-Pope, 2008[89]) concerning the experience of people descending stairs in different contexts. (Boxes 4, 5 and 7).
- Confirmatory case study known as the 2008-2010 case study which involve the selection of six buildings[90], and the survey, observation, recording and analysis of trial evacuations in each of the buildings, classifying and comparing the results with those of the explanatory studies and developing findings from those. (Boxes 2, 3, 6 and 9a-9c). This confirmatory case study comprises three study cycles with minor improvements[91] being made in the survey data collection method concerned with the measurement of fitness (Sjostrom et al, 2005).

[86] Delphi group process will be explained in another section based on work of Hsu and Sandford (2007) and utilising a Nominal Meeting format because of time constraints (Graefe and Armstrong (2011).

[87] The focus group studies each contained a mobility test so that descent speeds of the groups could be compared. Provided data to explain falling risk associated with the 2008-2010 trial evacuation survey respondents.

[88] Transcribed survivor accounts of stair descent during the WTC 9/11 Incident.

[89] Parker-Pope (2008) of the NY Times facilitated a blog/ chat-room asking the question of whether people in the community were generally fit enough to survive an emergency. Comments transcribed by means of content analysis.

[90] Selection is outlined in Chapter 4 following the method used in the 1980 Study.

[91] Known as Plan-Do-Study-Act cycle which is commonly used in Healthcare and other similar fields to improve the quality or reliability of a process or study (NHS, 2008)

Because of the flexibility that is always associated with the case study method (Gray, 2009) two author based case studies were added to the third cycle of the 2008-2010 to further investigate questions associated with assisted evacuation stair descent and the dichotomy associated with wider stairs[92]. (Boxes 3, 6 and 8).

- The development of findings occurs throughout the process as the theory developed from the Exploratory case study is compared initially with the additional preliminary results from the Explanatory case studies. (Boxes 7 and 8). Box 9a-9c is where conclusions and findings are drawn from all the studies together. It is here that a longitudinal comparison can be made between the exemplar buildings from the Exploratory case study and those from the 2008-2010 trial evacuation case study. The conclusions from the latter can also be further explained by the Explanatory case studies e.g. especially in terms of the falling risk associated with the performance of some individuals.

Analytical framework for relating context to the individual stair descent performance outcome.

Chapter 2 describes the Root Cause Analysis Model that is used to demonstrate the level of individual performance in stair descent in the context of the associated intrinsic and extrinsic factors. This Model is used extensively in the quality co9ntrol of health and safety activities (Portwood and Reising, 2007). The derivation of the "model" or framework used to demonstrate relationships

[92] The assisted escape case study is a field test of an evacuation chair device with a capacity of 200Kg to test the descent speed findings of Adams and Galea (2010) and to compare the results with descent speeds in the trial evacuations of the 2008-2010 Buildings (M1-M6). The dichotomy associated with wider stairs was associated with handrail reach for persons requiring support from a handrail on each side of the stairs. The case study here was of an evacuation of a seven storey office building in Christchurch during the February 2011 earthquake.

between the contextual factors and individual descent performance or capability was based on the Functional Capacity Evaluation Model of Matheson et al (2003). RCA using the Ishikawa Chart can follow a "structured" deductive problem solving process suitable for brainstorming (Portwood and Reising, 2007). It (Figure 3-6) is therefore to be used for the following purposes:

- A framework and tool for the Delphi group to identify the contextual factors for placement on the "fins" of the Ishikawa Chart and the nature of the outcome on the spine resulting from the interaction of the factors on the spine of the Chart.
- A prompt for the members of the focus group where only the classifications of the contextual factors determined by the Delphi Group are noted and where the factors making up those classifications are determined by focus group participants.
- A framework to summarise the results of each case study and then again to combine the results from each case study as an entity e.g. explanatory and 2008-2010 trial evacuation case study.

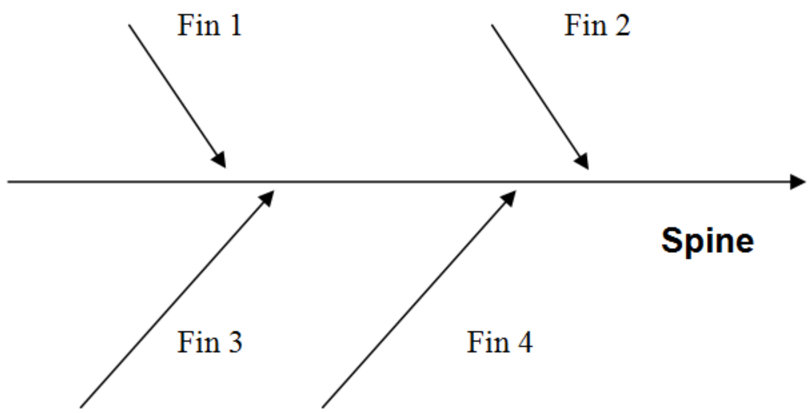

Figure 3-6: Ishikawa Chart as a framework

For a full explanation of the use of the framework as a FCE tool (Matheson 2003) see section 2.9 of Chapter 2.

3.3.3 Time Horizons

Peeling the next layer of the Research Onion (Saunders et al, 2007) it is necessary to establish the time horizon of the PhD Case Study (a multiple case study). In this instance the Exploratory case study, which is a re-analysis of the author's 1980 study which comprises a total of eight building trial evacuations from which two representative exemplar buildings are selected for further comparison with those from the 2008-2010 trial evacuation case study, provides the opportunity for a longitudinal comparison. The purpose of this longitudinal comparison is to establish whether there is any difference in the stair descent ability of individuals over the last three decades as claimed by Pauls, Fruin and Zupan (2007). It is considered that is possible to do this because the data collection methods have been kept in sync as demonstrated diagrammatically in Figure 3-4 above. This is not strictly a longitudinal study in terms of participants but rather a longitudinal comparison of cases where the Exploratory case study is part of a multiple case study (PhD case study)[93].

3.3.4 Data Collection and Analysis Overview

The Data Collection layer of the Research Onion (Saunders et al, 2007) shows up the mixed methods nature of this PhD case study as suggested by Gray (2009) and Amaratunga et al (2002). The methods utilise a combination of qualitative and quantitative methods that are consistent with case study methodology (Yin, 2009) and triangulation to explain findings and interpretations (Hales, 2010).

The methods used are summarised as follows:

- **Exploratory case study** – re-analysis of descriptive statistics from the 1980 SPSS V2 hardcopy data along with observation notes and explanation of case or building selection criteria. This study is augmented

[93] In strict accordance with the selection of case studies as suggested by Gray (2009) and Yin (2009).

by a Canadian study carried out in association with the 1970 NRCC studies as shown in Box 1 of Figure 3-4 (Beck 1977). The latter contains descriptive statistics and chi-squared correlations showing up significant relationships between contextual factors and individual performance.

- **Explanatory case studies** – These studies comprise the following and the associated methods:
    - *Delphi Group*: utilises a form of the Delphi group known as the Policy Delphi (Turoff, 2002) where experts attend a facilitated meeting but where consensus is not used to reach a combined result based on deduction but rather on agreement not to delete. The Ishikawa Chart is used in a stripped down format for the experts to establish the context and performance issues.
    - *Focus Groups*: Three focus groups were assembled to complete a "bottom-up" study of the context and its impact on their descent capability or performance in line with recommendations of Krueger and Casey (2000). There were three focus groups being one of mature age individuals (>45 years as defined in Chapter 2), fuller figure individuals (> class 1 obesity as defined in Chapter 2) and lastly a benchmark group for comparison comprising younger and fit office workers as determined by the IPAQ system (Sjostrom et al, 2005). Methods involved administering the Ishikawa Chart in a stripped down format with only the context classifications noted on the "fins" (Figure 3-6) and an explanation of what the spine (Figure 3-6) represented in "layperson" language as a prompt and getting the participants to list those contextual factors they thought were critical on the chart.

They were also required to complete same questionnaire used in the third cycle trial evacuation survey to supplement the Ishikawa Chart. On completion of these tasks they were asked to undertake a mobility test from which their stair descent speed could be calculated (Reiner et al, 2002). There were approximately 10 persons in each group and SPSS V16 was used to code and analyse the questionnaires which were triangulated with the descent speeds recorded using Dictaphones. Focus discussion was also recorded on Dictaphones which were used in association with the other instruments.

- *Content Analysis Studies:* Two studies are involved here. The first is a transcript of the WTC 9/11 incident survivor recounts of their evacuation experience as recorded by Dwyer and Flynn (2004). The second is a record of chat-room comments recorded on a facilitated New York Times (Parker-Pope, 2008) dealing with the fitness of people to survive an emergency. The comments mainly revolved around the use of and the problems associated with multi-flight stairs. Content Analysis is a qualitative method suitable for abstracting information from "media" documents (Heuer et al, 2011; Hsieh and Shannon, 2005 and Zhang and Wildemuth, 2009). A simplified method was developed for classifying the content and that was the classification developed by the Delphi Group. Text was highlighted from the "content" and these formed "comments" which were allocated between the various classifications. Axial coding (Strauss and Corbin, 1990 and Mars et al, 2008) was used to further classify the "comments" into sub categories under each classification e.g. stair width under STAIRS. The frequencies of coded information were established using simple descriptive statistics in order to rank the "comments".

- **2008-2010 trial evacuation studies**

  This is the case study that has been broken into three cycles to allow for improvement in the design of the survey questionnaires between each cycle due to the construct validity of the fitness self reporting instrument being used. The self reporting system associated with the original questionnaire developed from the NRCC template was not considered by one of the Delphi Group members to be adequate so she advised the author to try a validated self reporting system and compare the fitness measures with the results from the first two cycles. The IPAQ system was selected (Sjostrom et al, 2005). Six buildings were selected using the criteria from the Exploratory case study and as explained in Chapter 4. The stairs were measured up and converted into categorical data as shown in Appendices A4 and A7 in accordance with templates representing the contextual issues established by the Delphi Group for the extrinsic factor classification of STAIRS. Trial evacuations were conducted in each one of the six buildings being recorded on video camcorders located on set floors, observed by a team of qualified observers recording their progress on Dictaphones, and the participants surveyed via a questionnaire a copy of which may be found in Appendix A3. The questionnaires were collected and SPSS V16 used to code and analyse the data using descriptive statistics, correlation analysis and regression analysis. Data was also reduced using a combination of factor and causal analysis (regression). The survey results are triangulated with the observed results using a system that is described in a subsequent section. The Explanatory studies are also used to further explain the results in the form of discussion.

- **Author based case studies –** There are two case studies. These case studies were found to be necessary on completion of cycle 3 of the 2008-2010 trial evacuation studies in that there were two issues that required further study. The case study method is flexible (Yin, 2009) and therefore permits the addition of subsidiary cases that were not included in the original selection[94]. The first case was to test the findings of Adams and Galea (2010) concerning the ease of using an evacuation chair device in a group of people descending the stairs. The original study had only tested a device with a capacity of 75Kg. The Fuller Figure focus group identified the possibility of requiring a device with a capacity of 200Kg. The method used was an on-site test using the author with additional "padding" as the subject on a stair with a pitch of 38^0 plus using fully trained operators as was the case with the mobility impaired female person in the WTC 9/11 incident study (Zmud, 2007 and Dwyer and Flynn, 2004)). The procedure is fully described in Chapter 4. The results are presented and discussed in Chapter 7 and Appendix A7. The issue of wider stairs had been raised in a number of studies (Pauls, Fruin and Zupan, 2007 and Peacock et al, 2009). During the Christchurch earthquake in February 2011 the author took part in an emergency evacuation of a seven storey office building. The author is obese with a BMI of 33 at the time. He has lower limb pain and a fear of falling. The stair was provided with two handrails and was 1000mm wide between walls. The writer held up a large group of people because of his slow descent speed and also that he needed to grasp both handrails for support. The method used to transcribe this study was to recreate the "train" of events by self observation and interviews of colleagues on the day of the event. The question that was asked was:

[94] See Box 2 of Figure 3-3 for initial process step. The decision to include the two additional studies was made during the analysis of the 3rd cycle of the 2008-2010 trial evacuation studies as this is where the two issues were identified.

"*What would have happened if the stair had been 1500mm between walls so as to allow for overtaking*[95]*?*

The time line was recreated and the results analysed using the Ishikawa Chart to study the level and context of the author's performance. The site is described in Chapter 4 and analysed in Chapter 7 after the 2008-2010 trial evacuation studies.

- **Analysis and Findings**

  The author's 1980 study hardcopy that was available was re-analysed in Chapter 5 to form the theory for the analysis of the main 2008-2010 trial evacuation case study data in Chapter 7. It was initially compared with the results of the Explanatory case studies in Chapter 6. In each case the analysis and discussion was summarised in an Ishikawa Chart so that the individual stair descent performance issues could be viewed in context.

The Explanatory case study results are all analysed and discussed in Chapter 6 using the mixed methodology[96] described above. The outcome of the analysis was used to explain or otherwise the outcomes from the 2008-2010 trial evacuation studies. Once again the combined outcome is presented in an Ishikawa Chart at the end of Chapter 7,

Conclusions are drawn from Chapter 7 and presented as findings in Chapter 8 in terms of the delivery of the PhD Case Study aim and objectives. The findings are also examined with implications for the future and study limitations established. The principles advised by Yin (2009) were followed and a combination of bottom-up and top-down

[95] The author still would have needed to use the two handrails for support so that there were issues of reachability and group delay.

[96] Content analysis for the media type information, Delphi group process to establish the context and performance parameters, and focus groups to compare groups with varying functional abilities in terms of fitness with those in the 2008-2010 trial evacuation case studies.

reasoning used especially in integrating the results from the multiple case studies forming the PhD Case Study.

3.3.5 Reliability of Research Process Design.

According to Yin (2009) there are four main heads of consideration for the design of any research process, especially that involving the Type 3 or multiple case studies. These heads comprise:

- Construct validity
- Internal validity
- External validity
- Reliability

Construct validity

One problem associated with case studies involving mixed methods is that the operational procedures for gathering data may be seen to be based on subjective judgements could be used to collect the data. Correct operational procedures therefore need to be adopted for the concepts being measured (Yin, 2009) e.g. structured content analysis for deriving data from media. Correct operational procedures apply especially to the survey, observation and recording of the trial evacuations so that the contextual and performance issues are comparable between buildings, otherwise generalisations cannot be made. The procedures for each case study were designed with this in mind including the Exploratory case study. The construct validity of the overall PhD Case Study is supported by multiple sources of evidence[97]. The procedures are described in Section 3.4

Internal validity

Internal validity in case study design is concerned with the creation of the ability available in the analysis of the data to establish causal relationships where one condition can lead to another (Yin, 2009) e.g. relationship between obesity and stair pitch to contribute to falling. It is not normally of concern in studies such as those of the trial evacuations which are just standard case studies but it can be of use in the analysis of descriptive statistical data for each trial evacuation. Patterns or trends may emerge. Pattern matching is a technique that needs to be available (Hak and Dul, 2009) here where "trends" or "directions" implied by the data can be matched between cases so that generalisations can be made (Yin, 2009). Spurious relationships can be dispensed with being one of the purposes of the inclusion of the Explanatory case studies to explain data from the main 2008-2010 case study.

External validity

One of the main reasons for selecting the case study method besides its flexibility is knowing whether or not the findings are generalisable beyond the immediate case study in question. Replication logic can be used to support this type of validity (Yin, 2009). Also when a finding appears to be generalisable such as the causes of falling the finding that may be generalised is the individual is hurrying (Mademli et al, 2008) which can represent a group of factors.

[97] One of the main major strengths of mixed methods is the use of triangulation to tie the evidence together so that reliable conclusions can be drawn. This also includes the integration of data from the Explanatory case studies which form part of the 2008-2010 case study in association with the trial evacuations. The chains of evidence also need to be clear. The reliability is therefore drawn form rigorous properly applied operational procedures.

Replicating can be achieved across a number of cases and is one of the reasons for the selection of a range of buildings and stair types in the 2008-2010 trial evacuation study.

Reliability

Reliability is most likely the one that is the most familiar in research design. This relates to the replication of protocols between cases (Yin, 2009). For example the content analysis procedure followed between the WTC9/11 incident study and the New York Times Blog study used a common information classification framework and then axial coding to populate the classifications (Strauss and Corbin, 1998). The classifications comprise the context made up of extrinsic and intrinsic factors associated with descent of multiple flights of stairs. Reliability is directly improved by the use of RCA Analysis across all the case study types (Portwood and Reising, 2007) and the associated Ishikawa Chart (Ishikawa, 1982).

Triangulation

Triangulation of the data in the PhD Case Study mainly applies to the 2008-2010 trial evacuation case studies (part of the 2008-2010 case study). There are three sets of data from the trial evacuation studies being:

- Survey based i.e. survey of the office workers completing the trial evacuations copies of which may be found for each cycle in the Appendix A3.
- Observations by observers in accordance with a written set of procedures from Dictaphone sound files where the observers descended the stairs with the office workers from each trial evacuation and recorded their progress.

- Observations of video captured visual images of evacuating office workers where their progress, pattern of movement and intrinsic characteristics are recorded to a time based stair descent spread sheet using Excel®. The x-axis would represent the time at entry of the first evacuee into the stairs extending to the time that last person passed through the final exit to that stair. The y-axis represents the number of levels in the building.

The process of triangulation will be in accordance with the guidelines set down by Hales (2010). Triangulation relates to evidence and to its reliability. It is summarised and explained in Figure 3-7

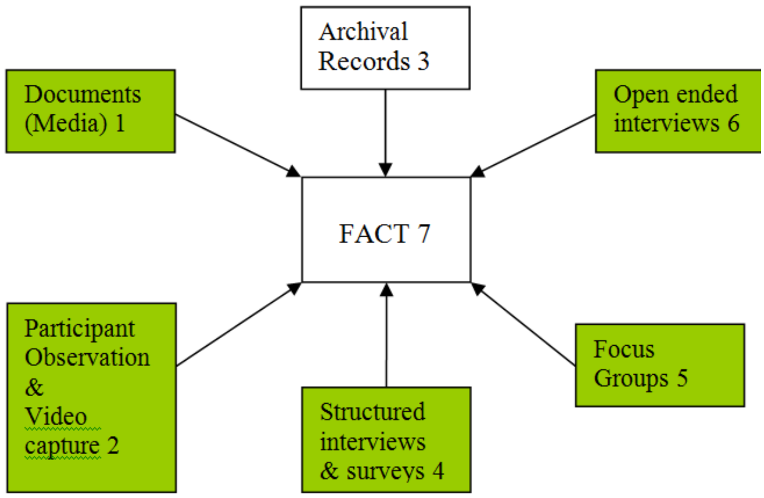

Figure 3-7: Check for convergence of evidence in PhD Study
(*Derived from Yin (2009)) – Green highlighted boxes indicate techniques used*

The collection from multiple sources places a burden on the researcher, but can be extremely useful in checking evidence i.e. showing that evidence converges. A simple example of this is the formation of groups. The survey respondent indicates that they entered a stair with a friend or in a group as a direct answer to a question in the survey questionnaire. The observer descending the stairs as part of a group can confirm this as can an observer transcribing video captured evidence to a spread sheet (Boxes 2 and 4). The range of group behaviours that could be expected could also be triangulated (Boxes 1, 2 and 5). The classification of the context could also be checked (Boxes 1, 5 and 6). Where the findings confirm one another then the issue being checked is successfully triangulated. Even when one piece of evidence does not "converge" with the other, they may still be used to explain what is happening (Yin, 2009). Figure 3-7 therefore represents an overview of the triangulation process used in the PhD Study widely used in Chapter 7 and to establish findings in Chapter 8.

Conclusions on case study design

Reliability and validity are both grounded in evidence and method protocols. The design must therefore:

- Show that the analysis relied on all available evidence.
- Challenge the analysis via the main rival theories e.g. obesity vs. descent speed or obesity vs. fatigue (Galea et al, 2008; Proulx et al, 2007; and Peacock et al, 2009).
- Addresses the most significant aspect of each case study even if the data presented is in the form of "outlier"[98] events such as a fall (Pauls, 2011).
- Uses the author's prior, expert knowledge and experience to further the analysis as he was immersed (Yin, 2009) in both the exploratory and 2008-2010 case studies.

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[98] The term outlier is used here in terms of frequency where the outlier represents a very low frequency of occurrence of a variable that is an extreme of the action of descending stairs which comprises a series of small falls from which the person recovers (stability) whereas a fall as defined in the text is where someone comes to rest on the ground and is most likely injured (Tinnetti et al, 1988). See also Pyle (1998) for definition of outlier dealing with frequency of occurrence

Finally considering the objective of the PhD Case Study (1.3.3) it is necessary to consider the concept of categorical aggregation (Tellis 1997) as a more comprehensive method of analysis to pattern matching (Hak and Dul. 2007). Multivariate regression is extremely useful when the objective of a study is to test a relationship in the context of many other contextual or explanatory variables. A great deal of the data gathered has been coded into a categorical format so that some form of categorical aggregation may be required. This would mean the use of Multivariate Regression Analysis (Liang et al, 1992). Further reading and comparison of examples put forward by Liang et al, (1992) show that Logistic Regression if properly constructed can provide results that are comparable with the Multivariate approach (Miles and Shelvin, 2001).

3.4 The PhD Case Study Method and Description

The strategy adopted as a result of peeling the research onion (Saunders et al, 2007) in the context of the strategy adopted in the author's 1980 study[99] is basically a multiple case study using mixed methods (Gray, 2009; Yin, 2009 and Amaratunga et al, 2002). The PhD (multiple) case study comprises

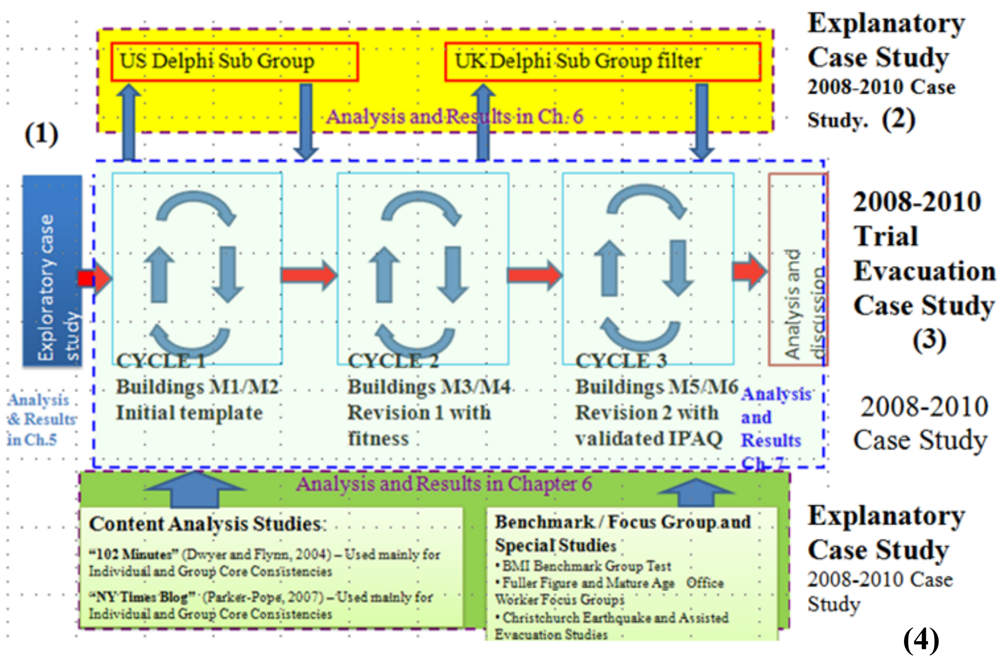
- **Exploratory[100]** – re-analysis of the author's 1980 study of trial evacuations on the Eastern Seaboard of Australia to set the theory and foundation for the entire case study. (Box 1 highlighted blue))
- **Explanatory[100]** – used to supplement and triangulate with the main 2008-2010 trial evacuation case study.(Box 2 highlighted yellow being the Delphi Group and Box 4 highlighted green being the focus groups.
- **Trial Evacuation study using multiple sources of evidence[100]** from different data collection methods being survey, direct observation of

[99] Study of the trial evacuation of eight buildings on the Eastern Seaboard of Australia in the 1980's which was never4 fully completed due to insufficient resources and funding.

[100] As defined by Gray (2009) and Yin (2009)

evacuees in accordance with formal instructions and data collection of evacuees captured on strategically placed video cameras within each stairwell. There are also two additional real world case studies associated with the trial evacuations described in the last section and also in Chapter 4.(Box 2 highlighted lighted blue)

The process is shown in Figure 3- 5 in terms of case study process theory and practice (Yin, 2009) and also in Figure 3-8 describing the interrelationships in terms of analysis and interpretation to aid with the description and methods covered in Sections 3.5 – 3.7. Figure 3-8 contains additional explanatory test in this regard.



Indicates the spine of the 2008-2010 Case Study Research Process ***designed in accordance with guidelines provided by Yin (2009) comprising three plan-do-study-act cycles (NHS, 2007) each of which involves the observation, survey and analysis of individuals descending stairs in trial evacuations of two buildings using mixed research methods.***

Also two author based case studies to clarify two issues raised in the literature review concerning assisted evacuation on the stairs and also increased stair width and handrail reachability.

Delphi Groups ***are formed and opinions obtained with consensus being reached in a two stage operation. These opinions, stated in the form of populated Ishikawa Charts, are used to frame and triangulate the survey and observation results from the building trial evacuations in each Cycle.***

Focus Groups ***are formed and individual and group opinions sought which are compared with responses from a questionnaire similar to those used for participants of the trial evacuations. They also undertake walking tests where the resultant walking speed is converted to stair descent speed (Riener et al, 2002 and Fujiyama and Tyler, 2010)***

Benchmark Group of young fit office workers ***is formed to frame the analysis of the focus groups. A timed and audible record was made of the stair descent test of each member of the group.*** *A study of the performance of a " fuller figure" male in the evacuation of an eight storey building in the Christchurch Earthquake* ***is also included because of the uniqueness of the event but also to reinforce output from the Focus Groups and the impact of the critical extrinsic factors.***

Figure 3-8: Case Study Process – Section 3.4
(read in conjunction with Figure 3- 5).

3.5 The Exploratory case study

Section 3.5 should be read in conjunction with the Appendix A3, Chapter 4 and also Chapter 5.

3.5.1 History

The original 1980 trial evacuation study was carried out on the Eastern Seaboard of Australia in the 1980's by the author as a researcher with the University of Technology, Sydney. The study involved the observation and survey of the trial evacuations of office workers from eight office buildings, with two building in each of the cities of Brisbane, Sydney, Melbourne and Adelaide, The State building regulations covering the design and construction of the buildings were all based on the former Australian Model Uniform Building Code so that the egress requirements were basically the same. The research design and operational protocols for the project were set up by an expert group comprising Jake Pauls[101], Edwina Juillett[101], Jonathan Sime[101] and the author[101]. The group did not utilise the Delphi technique to carry out this design. They were responsible for the following:

- Establishing a process to deliver the objectives of the egress part of the overall project brief (not repeated here as original documentation is no longer available).
- Selecting the buildings to form part of the study in accordance with criterion they set. The buildings needed to be over 25m in height, have two stairs, one of which discharged to the outside at ground level with the other permitted to discharge into the ground floor lobby with the range of heights of the buildings extending from the 25m to a maximum height that the team could gain approval for a trial evacuation to be held where

[101] Jake Pauls then researcher with the National Research Council of Canada, Edwina Juillett a life safety specialist from the USA and Dr. Jonathan Sime then Research Fellow at Portsmouth Polytechnic and the author who was Principal Researcher in the faculty of the Built Environment at the University of Technology, Sydney.

occupants would be allowed to descend the full height. This height was some 45 storeys.

- Designing a survey that could be handed out to the evacuees as they exited the stairs without decreasing the flow rate and that addressed the project brief in terms of data collection. See Appendix A3 for a reconstructed copy of the questionnaire. The team also designed a coding system. The questionnaire and coding system were based directly on the same instruments used in the NRCC evacuations in Canada in the 1970's (Pauls, 1974).
- Designing the trial observation protocols and checklist for the observers who followed the evacuees down the stairs from predetermined floor levels and using Dictaphones which they turned on before the activation of the alarm the observers recorded the progress of the group they were following. A copy of the protocols is included in Appendix A3.
- Designing a video capture system that would record the exiting pattern of the "incident" floor population into each stair and also the final exits. The positioning at the final exits was to be such that the images would include the people handing out the questionnaires. The latter were numbered so that it would be possible to triangulate survey responses with their exit time as well as their floor of origin. It also allowed for the identification of the person on the videotape from the intrinsic characteristic questions asked in the questionnaire.
- Designing a stairwell measurement template.
- Testing the system on the first building including coding the questionnaire, analysing the results using SPSS V2.1 and transcribing the data from the Dictaphone tapes on to observation logs where descent times and associated comments were noted. Copies of these documents may be found in Appendix A3.

There were a total of eight buildings selected as noted above in line with the criteria and descriptions described in Chapter 4. The average height was approximately 24 storeys. Most of the stairs had a pitch of some 37^0 and 250mm treads and of concrete construction. Building 6 in Adelaide was not as steep as the other buildings as can be seen in Chapter 4. Each building had an evacuation plan in place.

The video cameras were fixed in position on the evening before the trial evacuation and questionnaires numbered and allocated to the stairs where they were to be handed out outside the final exit. The cassette tape recorders were also numbered according to the relevant floor level and tapes loaded. Watches were set to a reliable time source. All other equipment including batteries was tested and charged where necessary. A team of observers were assembled and trained prior to each exercise. These individuals had all participated in trial evacuations before so that they were familiar with the process. They were given observation instructions[102] and check lists. On the day of the exercise the team assembled in ground floor lobby of the subject office building approximately 20-30 minutes before the exercise was due to commence. The observers were assigned to set floors which was usually on a ratio of one every four floors[103]. They proceeded to their assigned floors about ten minutes before the sounding of the initial alarm and after everyone had synchronised their watches. The video cameras were turned on at the same time. The recorders were turned on five minutes before the designated start time with a reference start time recorded. Once the alarm sounded the observers proceeded to record the flow of people into their designated stair according to their gender recording “Q” for females and “P” for males. The recorder recording rate was set to real time so that it was a time scale in itself. In accordance with their instructions the observers entered the stairs with people in the last group. As they descended the stairs the recorded “landing”

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[102] See the Appendix A3 for a detailed copy.

[103] Set by the expert group based on their experience in previous studies (e.g. Pauls, 1974)

and floor number as they stepped on to the main landing on each storey. They also recorded the number of people in front of them on the flight, their distribution on the stair and the number using the handrail. Observers were also asked to report when they were slowing down, when others were entering on a level below them together with their floor number and the extent of the delay. Once they reached the final exit they reported this and made themselves known to the observer handing out the questionnaires. This report was also picked up on the recorder of the person handing out the questionnaires and could be cross checked by the research team. The video tape images were provided with a time stamp. The time at which the alarm was operated also provided a valuable cross reference.

The questionnaires were collected the following day from the floor wardens and sorted into floor levels. An average response rate of 25% was achieved. On completion of the exercise the tapes were removed from the recorders and the cameras. The expert group had designed observation logs for transcribing the results. The method used started with the transcribing the information from the final exit observers as this created the exiting profile by questionnaire number. Observers' tapes were then analysed followed by the video tapes. Gradually the entire stair descent and exiting sequence was reconstructed using the same technique used by Pauls (1988). An example of this document known as the stair descent chart may be found in Chapter 4 and described above. Each "path" represented the progress of an individual from their originating floor to the final exit. Observer comments could also be added relating to points in time and stair conditions at that time. The video tape evidence provided by the camera at each final exit allowed for the survey respondents to be identified. This provided valuable data for triangulation as described by Hales (2010).

The questionnaires from each exercise were coded and the data entered and analysed using SPSS V2.1 (see Figure 3-9). Each of the exercises for

Buildings 1-8 is summarised in Chapter 4 together with a description of each building together with all the other information that is still available.

Figure 3- 10: SPSS V2.1 Printout Example

The overall project was never fully reported but the author still had some hardcopy SPSS V2.1 printouts, some examples of the observation logs, building details and observation notes. A copy of the questionnaire was available but missing three pages. The questionnaire was reconstructed and is included in Appendix A3 with a summary of the information that was abstracted from it for re-analysis in the Exploratory case study.

3.5.2 Exploratory Case Study Method

The only data remaining from the 1980 Study described in the previous section was:

- Hard copy SPSS V2.1 Data Analysis Printouts

- Some examples of observation logs
- Partial copy of questionnaire which has been reconstructed from information from the computer printouts.
- Some examples of completed observation and video tape logs used to prepare stair descent charts an example of which is included in Chapter 4 for one of the buildings.
- Some copies of observation notes including a description of a fall due to vertigo in Building 4.

The data that was most suitable for re-analysis in line with the aim of the PhD case study was required to answer the following questions:

(a) Whether or not it was feasible to continue a similar current case study in line with the Aim of the PhD Study as stated in Chapter 1? (Yin, 2009)
(b) The feasibility of using findings from the exploratory case study as the basis of a longitudinal link with the findings of the 2008-2010 Case Study?

The data that was most suitable fitted within the classifications used to interrogate the literature in Chapter 2 as well as forming the context in which the performance of office workers going down multiple flights of stairs was to be studied. These classifications are also confirmed by the Delphi Group as presented in Chapter 6.

The original analysis was carried out using SPSS V2.1[104] and was archived on magnetic tapes. The latter were destroyed when the research was terminated. The only data that remained was in the form of hard copies of tables

[104] Statistical Package for the Social Sciences Version 2.1

and project notes. This section shows the data source[105] and makeup for the exploratory case study.

Original survey design and data collection

The original questionnaire formed the basis of a survey of the total evacuation process and other emergency related issues. The questionnaire was a survey tool used to elicit and record the responses of office workers to a trial evacuation in their place of work. Not all the questions forming part of the original questionnaire are therefore directly applicable.

The questionnaire was originally divided in to the following broad sections:

(a) Early stages of the evacuation (including level on which they commenced the evacuation)

(b) Movement to and down the stairs

(c) Reconstructed questions covering

- Physical characteristics
- Fire warden status, role and experience
- Organisational role and status
- Impact of going down the stairs
- Stair choice
- Group actions and experience
- Location at time of alarm
- Obstructions on stairs
- Functional limitations and difficulties with stair traversal
- **Estimated descent capability**
- Normal stair use – level of fitness

[105] Data source referred to here is the questionnaire.

The questionnaire included in Appendix A3 has been highlighted in accordance with the data classifications referred to in Chapter 3 and analysed in Chapter 5. The classifications are shown in the following section.

Table 3- 2 : Classifications of 1980 data for further analysis in the exploratory case study.

- Extrinsic 1 - stair environment and location
- Extrinsic 2 – stairs
- Extrinsic 3 – handrails, lighting and maintenance
- Extrinsic 4 - density - others
- Extrinsic 5 - delays – others
- Extrinsic 6 - group formation
- Intrinsic 1 – confidence
- Intrinsic 2 – ability
- **Intrinsic 3 – fatigue and distance**[106]

Building One	13 storeys / 5 levels of car parking
Building Two	19 storeys
Building Three	33 storeys
Building Four	45 storeys
Building Five	7 storeys
Building Six	16 storeys
Building Seven	20 storeys
Building Eight	19 storeys

Table 3- 3: Summary of building heights

[106] Taken as an initial indicator of individual performance and included an estimate of how many storeys the respondent estimated they could cope with.

The response frequencies are all contained in separate tables as set out in Appendix A5 being for each of the eight buildings summarised in Table 3- 3 above. Fatigue and distance was initially proposed as the indicator of individual performance based on the claims of Pauls, Fruin and Zupan (2007) and Peacock et al (2009).

Supplementary evidence to further support re-analysis of 1980 data.

There was insufficient data to complete any form of analysis because the individual raw data was not available. The method was developed as follows:

- Seeing the 1980 Study survey design was directly based on the NRCC trial evacuation studies (Pauls 1974) it was considered that the resultant would be in sync and the intent of this argument is confirmed by Pauls (1988).
- Seeing the NRCC studies were conducted in Canada there was a need to compare the intrinsic population characteristics of the Australian and Canadian populations especially concerning age, gender and fitness indicators such as the level of obesity. This comparison was completed using statistics prepared by Rowland (1991) and similarities confirmed.
- Because of the similarities between the two studies it was decided to use a health science study of stair use of the same buildings (Beck 1977) that were studied in the NRCC study (Pauls 1974),

The Beck data (1977) and research method were studied and it was determined that it could be compared with the 1980 study data as partial explanatory case study[107] to establish whether or not the aim of the PhD Case Study could be delivered. The data from the Beck study (1977) was in the form of two tables listing the extrinsic elements for the three separate buildings and generalised across the three for the intrinsic characteristics.

When Table 3- 2, Table 3- 4 and Table 3-5 are viewed the contextual issues that are included complement those summarised in the Ishikawa Chart at the conclusion of Chapter 2,

.Extrinsic Element
No. Storeys
Clear Width of Stairs
Stair Pitch *Measured:* *Level of significance for occupants:*
Tread /Going *Measured:* *Mean foot size:*
Riser *Measured:* *Trip hazard:* *Comments:*
Handrail *Height:* *Graspability:*
Lighting / Visibility
Distraction
Conspicuity/ Legibility
Ventilation
Maintenance
Temperature
"Locked in"[51]
General safety
Orientation and knowing location

Data available for three buildings being 5, 10 and 21 storeys in height, The completed table may be found in Chapter 5

Table 3- 4: Table of Extrinsic Elements from Beck Study

[107] This would be termed an embedded explanatory study i,e, embedded within the Exploratory Case Study (Yin, 2009)

Intrinsic Elements	Frequency (%age)
Age	
18-30	58.6
31-40	21.8
41 plus	19.6
Gender	
Male	49.25
Female	50.75
Fitness attitude	
(5) very conscious (4) conscious but only walk (3) somewhat conscious but most likely lazy (2) conscious and no action (1) no answer	(5) = 39.8 (4) = 44.8 (3) = 12.7 (2) = 2.5 (1) = 0.2
Reasons for not using stairs	
Health conditions including physical impairment, reduced vision and other	4.0
Vertigo and dizziness	2.7
Fear of falling	1.5
Stairs unpleasant	8.2
Job does not permit it	15.4
Takes too long	7.2
Don't know	7.6

Table 3-5: Table of intrinsic characteristics generalised across the three buildings in Beck Study,

The data is re-analysed in Chapter 5 in two parts. Firstly the Beck study is analysed and discussed as representing the fitness and stair use status referred to by Pauls, Fruin and Zupan (2007). The 1980 study comprising the intrinsic and extrinsic contextual elements referred to in Table 3-2 was summarised into a master table for all eight buildings so that pattern matching[108] (Hak and Dul, 2010) would be possible. This was especially relevant given density[109] may

[108] Pattern matching in terms of trends based on similarity or changes due to building height or distance (Peacock et al, 2009).

[109] That is number of people per m^2 of stair plan area

indeed mask fatigue (Galea et al, 2008 and 2011). Once the pattern matching was completed and the results discussed they were compared with the outcome of the Beck Study (1977) and conclusions presented in the form of an Ishikawa Chart at the end of Chapter 5. There was also sufficient data to carry out a regression analysis of distance and fatigue as well as overall population descent capability. The causal relationships (Blaikie, 2003) established were generalised (Yin 2009) across the studies to provide a preliminary indicator for further examination in the 2008-2010 case study.

Exemplar Building Comparison

Two of the eight buildings (Table 3- 3)[110] were selected as being representative of the eight buildings re-analysed in the Exploratory case study for further comparisons within the 2008-2010 trial evacuation buildings profile. The proposed comparisons are possible because the data is in sync[111] and also allow for a specific longitudinal comparison to be made. The elements that were in common are listed in Table 3-2. The comparisons are made in Chapter 7 and comments about apparent trends. Examples of these trends concern individual stair descent ability or performance generalised. The claims raised by Pauls, Fruin and Zupan (2007) are tested in Chapter 7.

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[110] Buildings 3 and 7 which were two of the only buildings which had not been refurbished and where access was still available so that the stairs could be re-measured and photographed so that the template as set out in Appendix A3 could be completed and included in the factor analysis of the factors in the STAIR classification.

[111] Commonality between the survey questionnaire design as shown Figure 3-4 where the extrinsic and intrinsic issues were in common with those from the 2008-2010 trial evacuation survey.

3.6 2008 – 2010 Case Study (Embedded Explanatory Case Studies)

3.6.1 Selection

The aim of the PhD Case Study is:

To study the performance of mature age office workers descending multiple flights of stairs in trial evacuations of high rise office buildings in the context of extrinsic and intrinsic factors.

Parker-Pope (2008) in an introduction to a community discussion on a New York Times Blog was whether or not the average person was fit enough to survive an emergency incident. This sought views and provided potential data for a study of the comments re stair use in trial evacuations. A further media study was carried out by Dwyer and Flynn (2004) from the interviews of survivors and also interrogation of telephone calls made by occupants of the two towers. After extensive searching of other similar studies (Fahy and Proulx, 2005), it was decided to select Parker-Pope (2008) and Dwyer and Flynn (2004) for further analysis as part of the embedded explanatory study (Yin, 2009).

The most likely intrinsic characteristics that would affect stair descent capability were fitness and these are more than likely associated with those who are obese (Bohannon, 1997 and Al-Abdulwahab, 1999) and over the age of 45 years (Fujiyama and Tyler, 2010 and Lauretani et al, 2003). The author was provided with an opportunity to design and conduct two focus group sessions using occupants from building M6 using guidelines provided by Krueger and Casey (2000) and Larson et al (2004) to ensure that every opportunity was provided to the group to develop the contextual factors that affected them when descending the stairs. The criterion for selecting the focus group members was that they were obese or over the age of 45 years which is the age of the mature office worker (MacGregor and Gray, 2001). Very simple invitations were sent out to the building occupants via the Health and Safety Managers of the bank who was the sole tenant of the building.

Two of the case studies selected thus far involved individuals who would not be classified as experts[112]. In order for the 2008-2010 case study to "continue on" from the 1980 Study there was a need to re-assemble an "team of experts" to establish the contextual issues from the "top-down" where they would be expected to develop a contextual classification system using the RCA Ishikawa Chart as a tool (Portwood and Reising, 2007). Nominal groups or the Delphi method were seen as being suitable for this study (Hsu and Sandford, 2007).

Three case studies were therefore seen as forming the embedded explanatory study for the overall 2008-2010 Case Study. The methods proposed are described in the next three subsections being;

- Expert Study – an adaptation of the Delphi Technique where the coding tool is the RCA Ishikawa Chart (Portwood and Reising, 2007).
- Analysis of media accounts concerning evacuation and stair descent using Content Analysis (Hsieh and Shannon, 2005 and Fahy and Proulx, 2005) and a combination of coding methods that includes axial coding (Strauss and Corbin, 1998) with the core consistencies framed by the Delphi group.
- Design and conduct of focus group studies following the guidelines set down by Krueger and Casey (2000) and Larson et al (2004).

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[112] An expert is generally defined in the Oxford English Dictionary as a person who has a comprehensive and authoritative knowledge of or skill in a particular area or field.

3.6.2 The Delphi Group (Embedded Explanatory Study)

The Delphi Technique in General

The Delphi technique is a widely used and accepted technique for gathering data from respondents within their field of expertise (Hsu and Sandford, 2007). According to Turoff (2002) the technique involves the setting up of a group of experts who are generally not known to each other and then to request them complete provide comments and estimates on a problem that is set by the study facilitator (Graefe and Armstrong, 2011). The survey is normally conducted by correspondence using a number of iterations. After each iteration the estimates and comments are summarised and sent back to the participants as feedback. The participants then revise their estimates etc. and return them as before. There may be up to four or five iterations with the final document representing an aggregation of the findings (Graefe and Armstrong, 2011). Seeing reliability is considered to be vital between cases in any multiple case study, replication in coding and framing of data is advisable (Yin, 2009). The RCA (Portwood and Reising, 2007) cause and effect approach was used as the framing tool and this is similar to axial coding based on functional similarities between the contextual issues and how these all relate to the study of stair descent.

The technique adopted

The objective of the proposed Delphi study was to:

"To correlate informed judgements in a topic spanning a wide range of disciplines"

This objective agrees with the purpose of Delphi group outcomes suggested by Hsu and Sandford (2007). The author developed a technique based on facilitated consensual opinion seeing this suited the RCA approach and still relied on the eliciting of the initial expert comments and estimates being carried out separately. The author was relying on a "tolerated" consensus i.e. one where the experts would agree not to delete certain opinions in the second round in a two-tier approach. Consensus is not totally ruled out by all experts on Delphi (Hsu and Sandford, 2007) so that a "tolerated" consensus was utilised.

A two-tier approach was used which involved the selection of a Delphi Group that comprised two sub-groups. The selection of group members was supposed to be based on one member not knowing the other (Turoff, 2002). This was a difficult requirement to comply with, given that the field comprises so few researchers. The US members did know each of each other. The UK members did not know one another and only one knew of the other. This was considered to be an even balance given the guidelines provided by Turoff (2002).

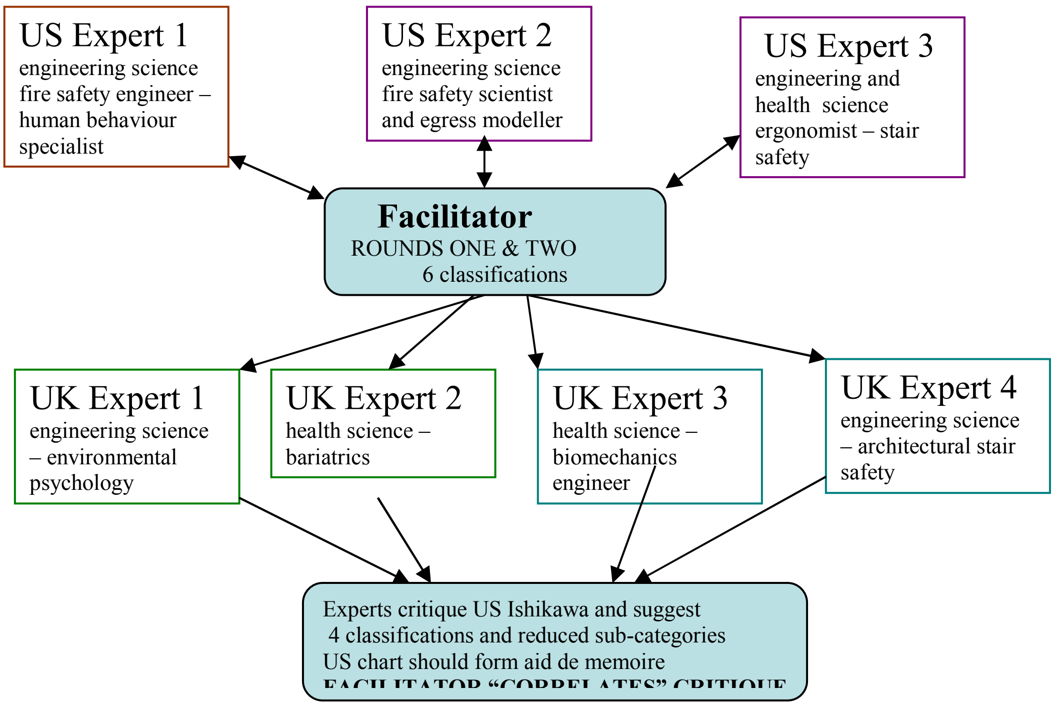

Figure 3-11: Explanatory study Delphi Group composition and process

The group was assembled as described in Figure 3-11 above. The group comprised two sub groups one located in the United States and the other in the United Kingdom. The experts are highly qualified in their field and all have published internationally in peer reviewed journals or have been part of an international research project connected with the problem. A summary of their curricula vitae may be found in the Appendix A3. The make-up of the group was as follows:

- The US Group members comprised one of the members of the original 1980 study expert group referred to under the Exploratory case study. The other two experts are involved in the post WTC 9/11 incident research programme at the National Institute of Standards and Technology (NIST) in the field of egress[113].
- The UK Group complimented the US Group in terms of disciplines in terms of the objective of the Delphi Group study as noted in the first paragraph of this section (Hsu and Sandford, 2007) in terms of their multi-disciplinary backgrounds.[114]

Due to time constraints a facilitated “Nominal Meeting” (Graefe and Armstrong, 2011) approach was used to gather and challenge the opinion. The anonymity requirements (Turoff, 2002) between members was achieved by the two tiered approach with one sub-group being located in the US and the others in the UK. The author acted as a facilitator to the group and the conduct of the study followed the process summarised in Figure 3-11 producing the outcomes in line

[113] US Group comprised Jake Pauls, Dr. Erica Kuligowski and Jason Averill.

[114] UK group comprised Mike Roys of the Building Research Establishment being an expert Architect on stair safety, Dr. Neil Reeves, biomechanical engineer specialising in stair climbing from the Metropolitan University of Manchester, Dr. Patricia McDermott, Environmental Psychologist from the School of Sports Science, University of Loughborough and Anita Rush, Bariatric Health Care Consultant from the NHS who participate in the study of Hignett et al (2007) concerned with the movement of morbidly obese people.

with Figure 3-12 below. Face to face interaction within the group was kept to a minimum especially so a dominant member would not take over the process with two facilitated meetings being held at different times representing a total of three rounds of the Policy Delphi technique (Turoff, 2002). The US Group met first in Gaithersburg, Maryland at the offices of NIST and the author acted as the facilitator. The brief was straightforward. An Ishikawa Chart (Ishikawa, 1982) with suggested classifications formed the questionnaire together with aim of the PhD Case Study. The instructions were to re-classify and then populate the context of individual stair descent performance in trial evacuations. A chart was handed to each member of the group and they completed the classifications. They returned the charts to the author who then circulated them with comments. The classifications were set at six as shown in Chapter 6. The charts were then handed out again and the members asked to populate each classification. On completion of this task the charts were circulated with a request whether or not there was anything further to be added. The facilitator then gathered up the charts and combined all the information on to one chart. This chart is "Outcome 1" as shown in Figure 3-12 below:

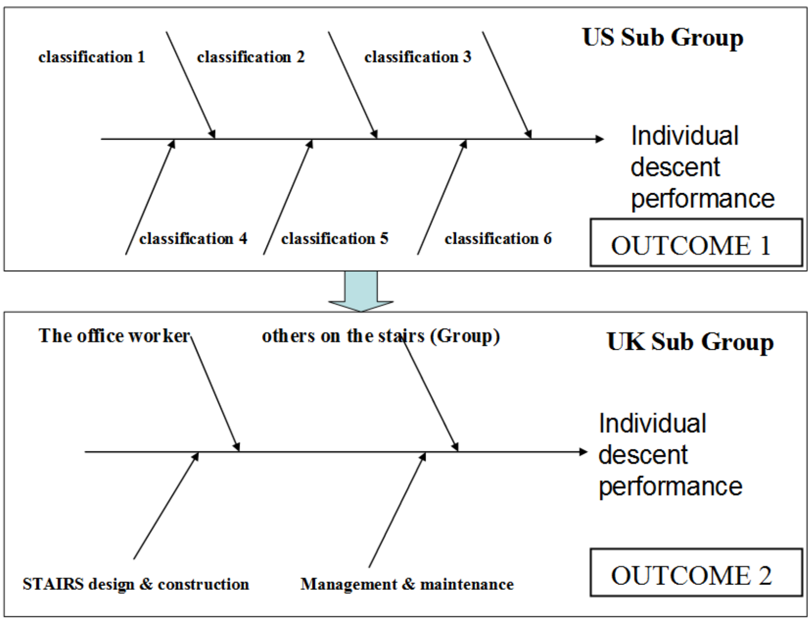

Figure 3-12: Delphi Group Two Tier Development of RCA Ishikawa Chart

The UK sub-group was assembled at the University of Salford shortly after the completion of "Outcome 1" and each member supplied with a copy of the document, the PhD Case Study aim and a request to modify the chart according to their field of expertise. Once again the author acted as the facilitator. The facilitator allowed the session to be more open-ended and was asked questions by the members of the group for more detail about the aim. Following these questions the members and the facilitator decreased the number of classifications. This new chart was then modified and repopulated by the group. Many of the original factors remained but regrouped. This revised chart is "Outcome 2" (Figure 3-12).

3.6.3 Content Analysis Studies (Embedded Explanatory Study

Content Analysis Approach

According to Hsieh and Shannon (2005) there are three approaches to content analysis. Fahy and Proulx (2005) studied media reports of the WTC 9/11 incident using the directed approach. The main purpose of content analysis is to interpret the meaning from the context of "text" data. The main differences between the three approaches are coding schemes, origins of codes and threats to authenticity (Hsieh and Shannon, 2005). The directed approach as described by Wildemuth and Zhang (2009) shows that the analysis (see Chapter 6 and Appendix A6) starts with a theory or research findings. In this instance the theory is represented by "Outcome 2" from the Delphi Group process (Figure 3-12) with the classifications being equivalent to the contextual classifications. The latter form the initial codes. The context analysis approach to be used is therefore a directed approach with axial coding being used to derive categories within the classification (initial coding) directly from the text. Content analysis is ideally suitable for media related text as well as the notes taken from focus groups.

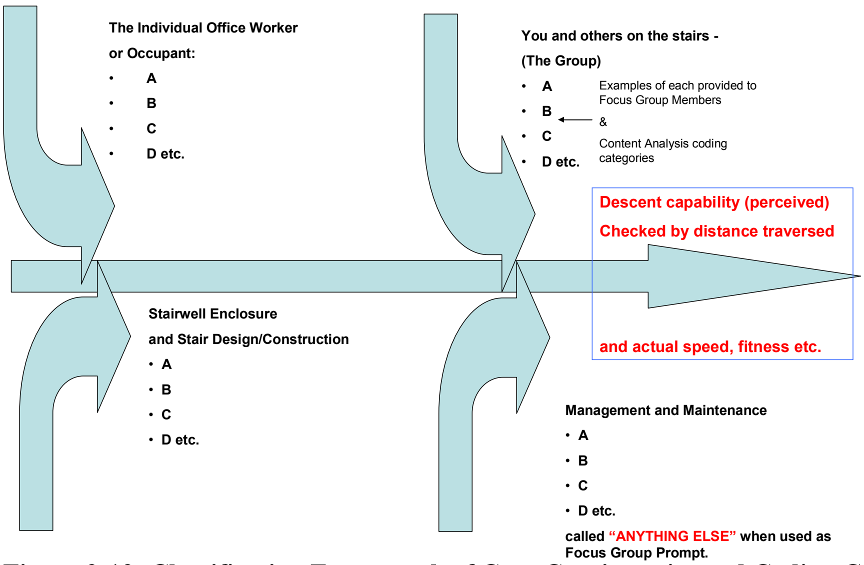

Figure 3-13: Classification Framework of Core Consistencies and Coding Categories.

Figure 3-13 shows the initial coding of the core consistencies (classifications). Further coding into sub-categories is seen as being part of the analysis (Hsieh and Shannon, 2005) and the complete list of subcategories may be found in Appendix A6. Mixed methods are used in the analysis where the frequencies of responses presented in the document text are measured and the pattern compared between the two studies described in the next section.

Figure 3-13 also shows the relationship of the Focus Group to the main coding classifications or core consistencies.

Selection of Study Documents

Media reports of WTC 9/11 incident survivors have been analysed by many (Fahy and Proulx, 2005 and Dwyer and Flynn, 2004). Dwyer and Flynn (2004) reviewed records of telephone calls from within the Towers as well as those of interviews with survivors. This study contained included many of the contextual factors included in the "Outcome 2" document (Figure 3-12) as well as setting up rival interpretations to another study of the WTC 9/11 incident by Galea et al (2008 and 2011) concerning fatigue being masked by the resting time provided by extensive delays and density (Spearpoint and MacLennan, 2012).

Parker-Pope (2008) a respected journalist with the New York Times was concerned with a series on whether or not the population was fit enough to survive an emergency. She facilitated a "blog"[115] on the issue and invited comments. This approach also corresponded with the theme of a seminal paper by Pauls, Fruin and Zupan (2007). There were over 100 comments, many of which dealt with community attitudes on group behaviour and fitness during evacuations in the descending stairs. The directed approach of content analysis was therefore suitable so that the Parker-Pope blog was selected for analysis (Parker-Pope, 2008).

Specific Methods of data extraction and analysis

The transcript was in the form of a published document on survivor interviews assembled by Dwyer and Flynn (2004) and a series of comments made by participants in a blog or chat room facilitated by Parker-Pope of the NY Times (2008)[116]. The text was interrogated and comments extracted that dealt directly with evacuees' experience within the stair shafts, formation of groups, evacuation management both central and local and description of their associated intrinsic characteristics. The comments were numbered in sequence and inserted in the "comments" column of tables with the format of Table 3- 6

The comments in the columns were then axially coded into columns representing the core consistencies that represented the Delphi Group classifications in Figure 3-13 above and as described above by inserting a red

[115] Definition of "blog" from Encyclopaedia Britannica: **blog,** in full Web log or Weblog, online journal where an individual, group, or corporation presents a record of activities, thoughts, or beliefs. Some blogs operate mainly as news filters, collecting various online sources and adding short comments and Internet links. Other blogs concentrate on presenting original material. In addition, many blogs provide a forum to allow visitors to leave comments and interact with the publisher. "To blog" is the act of composing material for a blog. Materials are largely written, but pictures, audio, and videos are important elements of many blogs. The "blogosphere" is the online universe of blogs

[116] The theme was whether or not people would be fit enough to survive an evacuation.

tick in the relevant core consistency column (Table 3- 6). Based on the context of the text the core consistencies were split further into sub categories as shown in the sub category extraction tables in Appendix A6.

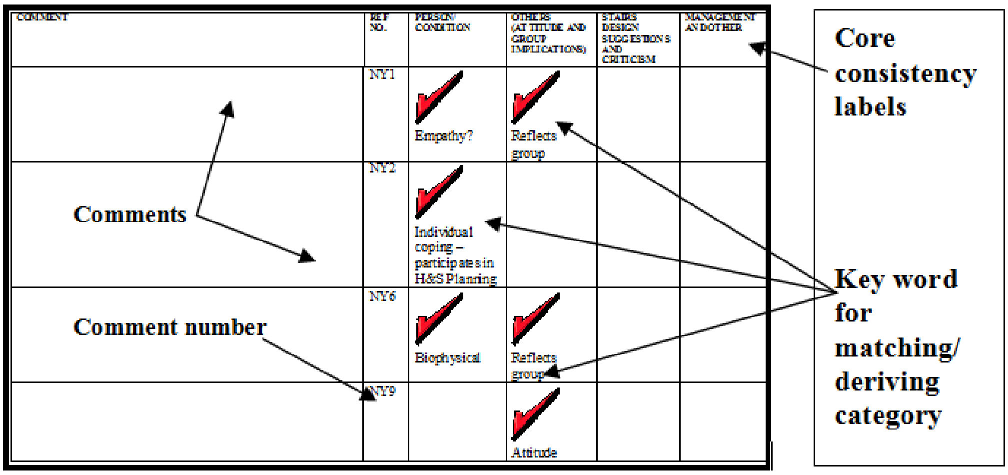

Table 3- 6: Specimen Directed Content Analysis Schedule

The sub categories were coded into tables with an appropriate key word for the next part of the analysis which is either matching it with a coding sub category or where one does not exist deriving a further category (Strauss and Corbin, 1998). The categories shown above are a result of the analysis of the two studies (Dwyer and Flynn, 2004 and Parker-Pope, 2008).

The schedules of the comments and core consistency and the frequencies of their subcategories are presented in Appendix A6 under each appropriate study (Dwyer and Flynn, 2004 and Parker-Pope, 2008).The analysis of these data is presented in Section 6.4 - 6.7. The results are also summarised on RCA Ishikawa Charts in Chapter 6.

3.6.4 Focus Group Studies (Embedded Explanatory Study)

Focus Groups

It is the focus group where high quality information can be gathered that comprise the experiences, perceptions and opinions of an individual descending the stairs (House and Howe, 1999). A focus group has been defined by Krueger and Casey (2000) as:

> *"A carefully planned series of discussions designed to obtain perceptions on a defined area of interest in a permissive, non-threatening environment"*

The real value of this approach is that the author intends to use it as a means of teasing out the real meanings of the task of stair descent from the users' point of view and experience (Caffarella, 2002).

	Focus Groups	Other Small Discussion Groups[1]	Large Discussion Groups[2]
Application			
Identify problems	Recommended	Recommended	Limited use
Design programs	Limited use	Limited use	Not recommended
Evaluate programs	Limited use	Not recommended	Not recommended
Educate or inform participants	Not recommended	Recommended	Recommended
Build consensus	Not recommended	Recommended	Recommended
Purpose	Designed to encourage divergent thinking and disclosure of personal perceptions and behaviors	Designed to study and/or generate ideas and solutions	Designed to build consensus, educate, or persuade
Participant selection	Participants are selectively invited, based on similar characteristics	Participants invited or required to participate because of their organizational affiliation. Similarity between participants is not a qualifier and may be a limitation in some situations.	Open to everyone in an organization or community
Group size	Group size from 6 to 12 individuals	Group size from 6 to 20 individuals	Group size from 6 to 100 or more individuals, depending on the issue
Event environment	Open, trusting environment	Open, trusting environment	Open, trusting environment

1 For example, Study circle, Delphi Technique, Search Conference

2 For example, town meeting

Table 3-7: - Comparing and contrasting focus groups and other types of discussion groups
Source – Larson et al, 2004, p2, Table 1.

Table 3-7 shows the selection of the focus group in this instance is appropriate, as the main thrust for the members of the groups was to identify problems (Larson et al, 2004). The main problems were then redefined as main causes. The Ishikawa Chart (Ishikawa, 1982) approach has a history of use as a problem identifying and solving tool that fits in well with qualitative research because it is dealing with complex data and opinions. It is used with Delphi Groups (Lumsdaine and Lumsdaine, 1995) even when consensus is not required. Other aspects that further justify its use to tease out the Delphi Group's findings are (Larson et al, 2004):

- It encourages divergent thinking so that seeing the two focus groups can represent the Mature Office Worker and the Bariatric or Obese Office Worker and that these two groups will bring many associated conditions to the table that are seen as functional limitations to stair descent (Reeves, 2008 and Booth et al, 2002).
- The only similarity between the members is their general grouping in terms of age and obesity.
- The groups were no larger than 12 or smaller than 6.

There is no doubt that focus groups share some features with other forms of group discussion. What sets this approach apart from the Delphi Group is that there was a controlled process and environment that was not threatening so that interactions could take place between participants. There was a structured directed content analysis process to code and interpret the data (e.g. grounded theory) and the groups were reasonably homogeneous as previously described (Larson et al, 2004). The other benefit is that the Ishikawa Chart could be used as a prompt with the four contextual classifications representing the initial coding regime of the content analysis method (Hsieh and Shannon, 2005).

The questions posed by the author in justifying the use of focus groups (Larson, 2004) were:

- *For what purpose is the information being collected or how will the information be used?*
- Answer: So that the meanings and completeness of the Delphi Group can be interrogated using the same tool. It was also intended to provide a good check on the language used in the survey questionnaires.
- *What resources and skills are available for the information gathering process?*
- Answer: A facilitator was required to lead the group discussions in a direct way. The Ishikawa Chart Branch Headings were modified so that they were meaningful to the lay person. The structure and working of the Chart was explained. The populating of the Chart with the perceptions, experiences and behaviour of the members of each group was explained by way of example. The facilitator needed to manage the conversations so as to maintain focus without threatening the members.

Focus Group – Operational Protocols

There are three Focus Group Studies[117] as described in Chapter 3 being:

- BMI Benchmark Group comprising 10 "young" office workers below the age of 40 years and one 40+ years who undertook a vigorous level of exercise in accordance with the IPAQ (Sjostrom et al, 2005) and was therefore classified as "fit".

- " Larger Figure" Focus Group comprising office workers with a BMI classification of overweight+(WHO, 2011) and who were conversant

[117] The three focus groups that represent the spectrum of performance according to the literature according to Ayis et al and which will provide comparative data on descent speed as an indicator f functional limitations. The benchmark group is of young adult office workers who are fit as measured under the IPAQ system (Sjostrom et al, 2005)

with trial evacuations being part of a building set up where the emergency control organisation was actively committed to full scale practices and had a limited functional limitation classification procedure in place that encompassed the model put forward by Matheson (2003).

- "Mature-Age Office Worker Focus Group comprising office workers with an age over 45 years of age (Kossen and Wilkinson, 2010) from the same building set up as the "Larger Figure" Focus Group. The BMI of this group varied as age was the sole criterion.

BMI Benchmark "Focus Group"

The "BMI Benchmark" Focus Group comprised observers from the 2008-2010 trial evacuation studies so that they were conversant in the gathering of data and with respondent occupant trial evacuation behaviour and stair use. The two other focus groups were selected from workers in the Sydney Building M6, one of the buildings studied in Cycle PDSA 3 of the 2008-2010 trial evacuation study. A validated self reporting survey form as part of the questionnaire integrating the IPAQ Short Form (Ottevacre et al, 2011 and Sjostrom et al, 2005) was used to gather further information so as to make the results more comparable with that from the PDSA Cycle 3 of the 2008-2010 trial evacuation study. A BMI Benchmark Focus Group provides a better view of the context when reviewing similar recent studies connected with the WTC 9/11 incident and associated research programmes (Galea et al, 2008 and 2008a; Peacock et al, 2009; Jiang et al. 2012; Boyce et al, 2011 and Peacock et al, 2012) when looking at actual descent speeds as opposed to those masked by extensive delays or density. A copy of the above questionnaire may be found in Appendix A3.

There were two sites for the BMI Benchmark Group[118]. The first was a 20 storey office building in Christchurch, NZ with scissor stairs (Figure 6-8). The second was the 32 storey office building which is Building M6 in the 2008-2010 trial evacuation study (Figure 3- 14).

Each member of the group recorded their descent on a Dictaphone. The participants were fit with their fitness having been measured using the IPAQ system (Sjostrom et al, 2005). There were a total of five in the Christchurch group and five in the Sydney group (total of ten members in the BMI focus group).

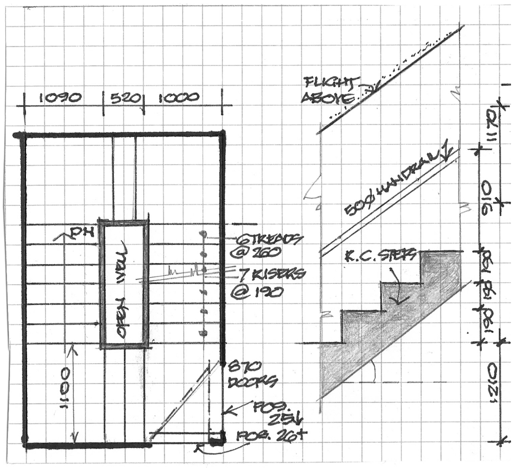

Figure 3- 14: Stair One Building M6

Diagrammatic Plan view - Stair One

CALCULATIONS

Storey height = 19X 190mm = 3.610m

Distance traversed = 9.058m per storey / 244.6m

Total traversed height to level 5 = 97.470m

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[118] The buildings were selected as being representative of the 2008-2010 case study building profile. The Christchurch building was 20 storeys which was less than the 25 storey measure of 50% of the population in the Exploraory Case Study and also representative of Building M4 and the other being M6 which was one of the highest buildings in the case study. Also two sites were used because of the dofferent types of stairs in terms of the number of turns per storey.

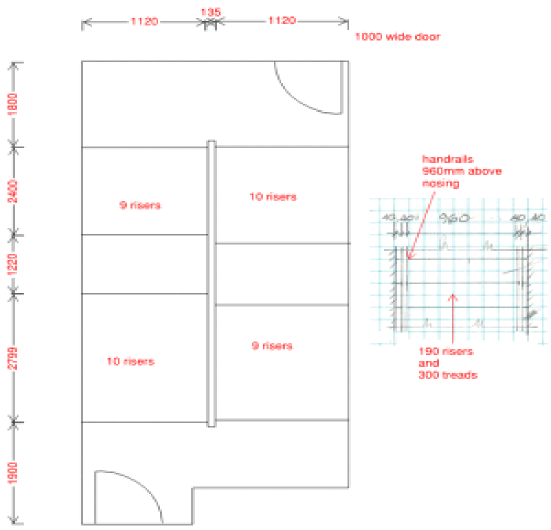

Figure 3-15: Diagrammatic Plan View of Stair 1 Christchurch Building (Represents M4)

M6 was used for the Sydney Group of 5 members. Stair 1 (Figure 6-8) was the stair selected and represented a steep stair of 37^0. Rich views (Templer 1992) provided a distraction through the wide void and there were four turns per storey as compared with one in Christchurch building.

The 5 group members were all fit being assessed as before. One member of the group was over the age of 40 years but played tennis and exercised regularly.

The results are presented in Chapter 6 and Appendix A6.

Focus Group Study 2 – Fuller Figure

The office building from which the two specialist focus groups (see next section for the Mature Age Focus Group Study) were drawn from was Building M6 of the 2008-2010 trial evacuation study. It was not possible to measure descent speeds for the members of these two groups for health and safety reasons[119]. The descent speed was calculated from a walking test based on

[119] Not permitted by the Building Owner's and Tenant's Health and Safety Management Team

the work of Riener et al (2002) and Fujiyama and Tyler (2010). A walking test was of 40m was applied which was converted to represent an average stair descent speed from studies on the relationship between the walking speed and descent speeds (Riener et al, 2002 and Fujiyama and Tyler, 2010)[120]. There is no doubt that fatigue could be taken into account based on the distance travelled using the same basis as suggested by Spearpoint and MacLennan (2012). This approach approximates that used in the six minute walking test which shows up the impact of functional limitations including fitness (Hulens et al, 2003).

There were a total of six members of the Fuller Figure Group where all the members were obese. Their intrinsic characteristics such as mass, waist circumference, height, gender, functional limitations, level of exercise and age were recorded on the questionnaires which were treated as confidential. The walking test was held first where the individual was required to walk a predetermined route at their comfortable walking speed. Their walking time over the 40 metre long "track" was measured by the author who also acted as the facilitator. On completing the walking test they were provided with a copy of the questionnaire which is included in Appendix A3. Details on the content of the questionnaire may be found in the next section.

[120]Triangulated with the author's own stair descent speed

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A(J)	F	Knee			✓		• Needs handrail to feel more confident • Signage to each level for orientation • Marking on steps for legibility
B((W)	M	0			✓		• Not wide enough between handrails • Treads too narrow • Stair design has not changed with body shape and foot size • All elements (steps/ handrails/walls) same grey colour – orientation – need to know level and direction of travel / impact on falls/ • Vital safety elements such as edge of treads and handrails should be highlighted • Must avoid 'whiteout' for reasons of the above and also if smoke penetrates stairwell • Wallpaper effect
C(L)	M	Reduced Vision			✓		• Poor edge delineation of steps – wallpaper effect • Whiteout effect where handrails and steps not marked • Where does each flight stop and start?
D(M)	M	Knees/ Height/large feet			✓		• Stairs too steep and treads too small • No variation in direction – repetitive turning – wallpaper effect compounded – dizziness • Disorientation with no signage / whiteout etc. • Very noisy – echoing from talking in groups – very intimidating will increase further with pressurisation fans and alarms • Temperature – e.g. in Adelaide was 46^{0}C
E(?)	M	Not fit Arthritis			✓		• No space provided on landings for resting • No space provided for overtaking - stairs

Table 3- 8: Example of Focus Group Coding Schedule.

When the members of the group finished filling in the questionnaires they were coded with a number specific to each member and locked away. Everyone then mixed socially over lunch prior to the afternoon discussion. The afternoon session commenced with the members of the group completing the Ishikawa Chart and inserting their own comments on each of the fins with any notes they wished to make on the spine concerning performance related problems. After 30 minutes the charts were collected and the discussion opened up. Each member of the group was asked to make any comments they wished to add to what they had already provided on the charts. They were also asked a small number of questions relating to improvements that they would suggest be made to the stairs, management procedures and the organisation of groups. Their views were also sought on assisted evacuation. All their answers were recorded in notes taken by the facilitator and also on a central Dictaphone placed on the table once permission had been given by the group. The analysis of the discussion and their comments on the chart were coded as

The recommendations of Krueger and Casey (2000) were complied with especially in terms of providing a non-threatening atmosphere and motivating the members to contribute.

Focus Group Study 3 Mature Age Focus Group

The members of this group were all over the age of 45 years in accordance with the definition of a mature age worker described in Chapter 2. There were a total of six participants including the author (as permitted by Yin, 2009). The BMI fluctuated but the number of functional limitations did increase. The details were once again recorded on the questionnaire a copy of which may be found in Appendix A3. The operational protocols and tests replicated those of the Fuller Figure Group.

Focus Groups - mixed method data collection

In line with the mixed method approach used in the overall PhD Case Study the following data collection tools are proposed:

- Survey questionnaire[121] replicating the 2008-2010 trial evacuation survey[122]
- Timed stair descent or mobility test so that descent speed can be linked to the group members' contextual factors[122].
- Completed Ishikawa Chart also used as prompt – directed content analysis.

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[121] The IPAQ questionnaire - IPAQ is the International Physical Activity Questionnaire (Sjostrom et al, 2005) that can be used to measure and determine self reported fitness.

[122] The members of each of the focus groups were occupants of building M6 and experienced in trial evacuations and the observers who had been trained in the observations of trial evacuations and were all certified practicing fire engineers experienced in evacuation analysis and also stair descent.

- Records of open discussion on Dictaphone and written notes from free discussion in group sessions.

The directed content analysis method is used to analyse the data from the group discussions. This method is described under the previous section dealing with the content analysis studies as the tool shown in Figure 3-13. Axial coding with functional similarities (Strauss and Corbin, 1990 and Mars et al, 2008) is the formal coding method used where the initial codes were set by the Delphi Group providing the framework for the focus groups. The observations of the stair descent and mobility tests were recorded in schedule form and presented in graphical format so that comparisons could be made between the groups and also triangulated with the results of the focus group surveys (analysed using SPSS V16). The method of triangulation (Hales, 2010) sifts out those comments from which "facts" can or cannot be "constructed". See Chapter 6 for examples of the above graphs and schedules.

3.7 2008-2010 Case Study – Trial Evacuations Study

3.7.1 Introduction

The 2008-2010 Trial Evacuation study is the main part of the 2008-2010 Case Study. Six buildings were selected for the study in line with the criteria set out in Chapter 4. They are also fully described in Chapter 4 and in Appendix A4. The average number of storeys was 24 which is only one less than the estimated descent ability or performance of office workers from the 1980 Study which was re-analysed for the Exploratory case study.

The data collection methods used for the trial evacuation part of the 2008-2010 Case Study comprised:

- Physical measurement and rating of stairs in accordance with the results of the Delphi Group determination and also the Literature review in Chapter 2.

- Survey of trial evacuation participants with questionnaires
- Observation and recording of evacuee performance on Dictaphones where observers descended the stairs with the occupants of the building and observed their progress and activities. The time scale was synchronised with the appropriate recording speed of the Dictaphone and with reference times recorded by the observer.
- Recording of evacuee performance and progress on video cameras using the camera time stamp information as the time scale
- Analysis of each set of results and triangulating between recorded data and survey responses.

In summary the selection range of the buildings varied from the minimum height which was equivalent to 8 storeys to the maximum number of storeys that the owner's health and safety team were prepared to evacuate as part of their total trial evacuation exercise. In this instance the maximum number of storeys was 36. The range is shown Figure 3-16. Also each of the buildings has a minimum of two stairs. The stairs and the associated stairwells were also measured up and diagrammatic plans prepared for each. These plans are included in Chapter 4. The measuring up and assessment of the stairs were carried out in accordance with a template where the factors under the classification or core consistency of "STAIRS"[123] were measured and rated on a nominal scale suitable for further analysis using the SPSS V16 Factor Analysis package (see Chapter 7).

[123] As defined by the UK Delphi Subgroup. The full template ios located in Appendix A3.

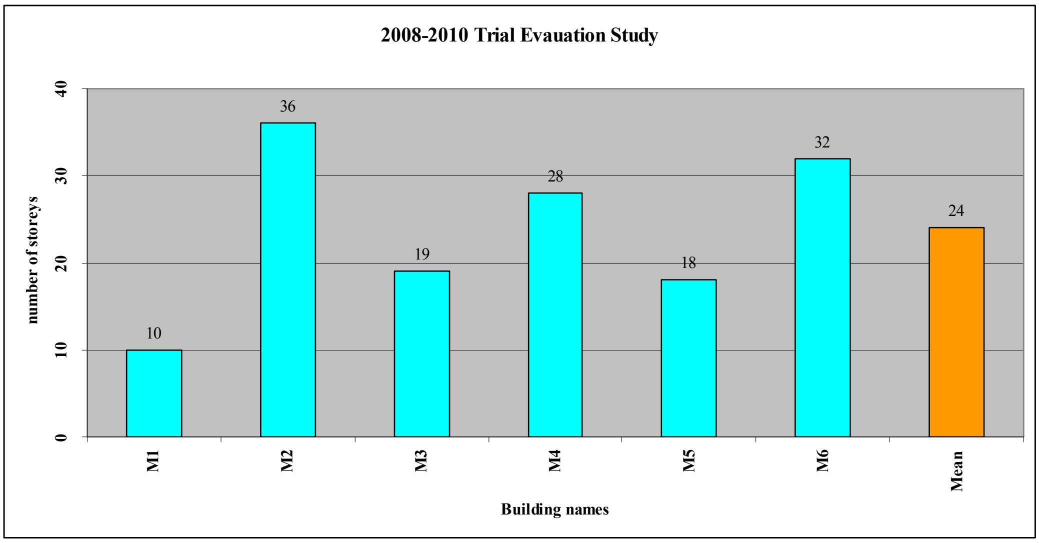


Figure 3-16: Range of building heights for 2008-2010 Trial Evacuation Study.

3.7.2 Trial Evacuation Organisation and Process

Letters were sent to the building owners outlining the research project and the extent of our participation in and observation of their next trial evacuation. A copy of this letter and the formal agreement is included in the Appendix A3 along with the details of how the Data Protection issues were to be dealt with. Ethics approval was also obtained from the University Ethics Committee prior to the conduct of any of the trial evacuations and focus group exercises.

In order for the study to reflect actual practice the procedures did not permit any form of alteration to the evacuation strategy, plan or management. An example of this may be found in the procedures for the stair descent observers where the observer is strongly advised not to interfere with warden procedures or evacuee behaviour. They were merely required to observe and record events during each drill.

Once the contract or agreement had been signed the date for the exercise was agreed and the researcher was permitted to enter the building and carry out the following tasks:

- Measure up the stairs in accordance with the standardised template (see Appendix A3)
- Meet the emergency response team for the building including the fire wardens, explain the programme to them and supply them with a copy of the questionnaire and make the necessary arrangements to hand them out to their colleagues after the completions of the exercise.
- Obtain permission for the placement of the cameras and also access the day before the exercise to fix them in position.
- Obtain a copy of the building evacuation plan and become familiar with the requirements.
- Agree a time with the chief warden for the observation team to gather in the ground floor lobby on the day of the drill.

On the day of the drill with all the cameras fixed in position, the observation team fully briefed, all their watches fully synchronised and their floors/ stairs assigned the observers proceeded to their floors ten minutes prior to the sounding of the evacuation alarm. The cameras were all switched on during this ten minute interval so that they were recording. The observation team were all in position five minutes prior to the alarm sounding and after having notified the floor warden that they were ready and in position. The observer also recorded a reference time on the Dictaphone.

The evacuation alarm then sounded and in accordance with their procedures the observers with their Dictaphones switch on began describing the activities on the floor. As the occupants started to enter the stairs their flow across the entry to the stairs was recorded using a simple procedure. The Dictaphone recording acted as the time scale for analysis of the descent after the trial evacuation. The observer entered the stairs as part of the last group and proceeded to descend the stairs recording on each level;

- The number of people in front of them on the flight
- Their distribution on that flight of stairs
- The number of people in front using the handrail
- Instance at which the observer placed their foot on the main landing at each level together with the number of that level.
- Other observations about other floors entering, mixing on those levels and the resultant delays
- Instances when the rate of descent slowed down or even stopped.

As each observer reached ground level they identified themselves on the last camera with their floor number, recorded the point at which they passed through the final exit and kept going until they were well clear of the building. They were required then to provide a further reference time, add any other observations they thought would be interesting.

After the exercise the team proceeded to remove the cameras (see Figure 3-17 for fixing detail) and cassettes from the cameras. Electronic sound files were created from the tapes and folders made with the data cards from each of the cameras. All of these were placed in a master folder for each trial evacuation exercise (Buildings M1-M6). These folders therefore contained the raw data for the reconstruction of the exercise using Excel®.

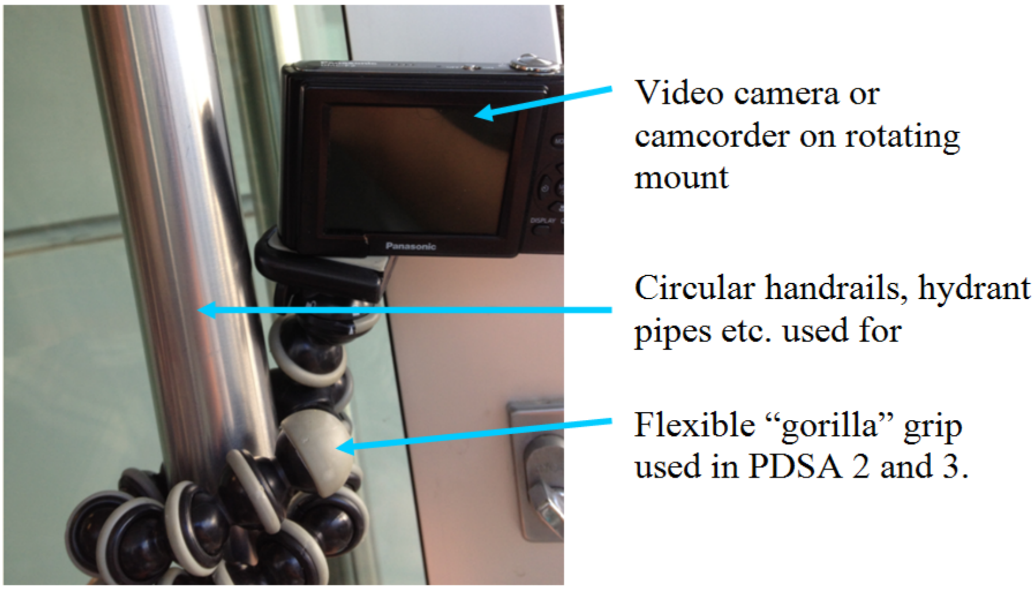


Figure 3-17: Typical fixing and mounting for video cameras and camcorders in PDSA Cycles 2 and 3.

(Tape was used in PSDA Cycle 1 and failed in Building M2 because of the heat – $45^{0}C$+)

The questionnaires were gathered up from the fire wardens the day after the evacuation exercise and coded using standard variable names representing the questions. A copy of this coding schedule may be found in Appendix A3. The data was then transferred on to an Excel spread sheet and then transferred into the SPSS V16 files ready for analysis.

This procedure was repeated for each of the buildings M1-M6. Summary descriptions of each trial evacuation exercise may be found in Chapter 4 and the reconstruction of the drill together with the observation schedules may be found in Appendix A7.6. Copies of the raw data are also available for further analysis in electronic folders attached to Appendix A7.

The method of data collection for the trial evacuations could be challenged by other egress researchers such as Averill (Averill et al, 2005) in the lack of automation used in the gathering of data to more accurately determine speed. Averill (Averill et al, 2005) used a combination of Radio Frequency Descent Devices (RFID's) and video cameras. The two systems could be interfaced. The author is required to defend his method and list the following reasons:

- It requires the placement of strategically located UHF devices.
- Electronic tags must be fitted to each occupant requiring a large number of tags per building and the risk of the tags not being returned. This was also seen as being extremely invasive by some of the building owners.
- The increased amount of interface between the various devices.
- Set up time available at each site.
- The overall cost was beyond the resources available to the author as he financed the entire study himself.
- The method used was in direct line with the 1980 study and the use of observers descending with the occupants provided a richness of data that would not have been available.

The letters of application and approval are located in Appendix A3 and can be used to substantiate the above especially in terms of the requirements for the observation team to be unobtrusive.

The other criticism would be the measurement of distance traversed from video footage. Normally The RFID's would most likely permit automatic measurement of the distance. The distance in the 2008-2010 trial evacuation studies was measured using measurements provided by the regime set out in Figure 3-19 where all horizontal and raking measurements were recorded separately. Key points on the video images were selected so that the distance could be calculated using information from Figure 3-19. This is considered to be satisfactory especially when the data is being triangulated with survey response data.

3.7.3 Data Analysis of Observations

The video tape files are rigorously analysed starting with observers and then evacuees. Data points are established using evacuee stair entry times and sequences established by the observers and then establishing progress data points for the same individuals as they are identified on the cameras on the lower levels. This is continued for those floors with observers with all the points being transferred on to an Excel® spread sheet. The same process is repeated for evacuees whose entry is recorded on cameras. Total individual progress is then determined by identifying the individuals as they pass through the final exit of the stair shaft. A graph is then drawn from the data point spread sheet with the Y-axis as the number of storeys or distance and the x-axis as elapsed time. The coloured lines on the chart (Figure 3-18) represent the timed progress of each individual with respect to distance. They are colour coded according to the floors the individuals entered from. The stair descent chart is therefore a reconstruction of the stir descent part of the trial evacuation exercise.

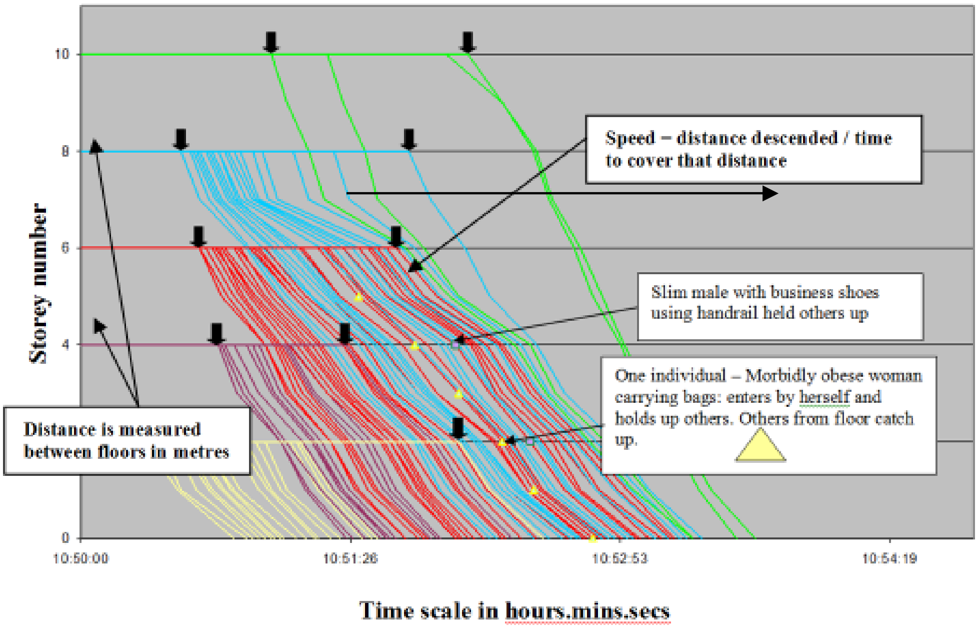


Figure 3-18: Typical descent chart where X and Y axis units are shown

(Coloured lines indicate the rate of descent for each evacuee – colour coded according to floor of origin. Also shows comments from observer)

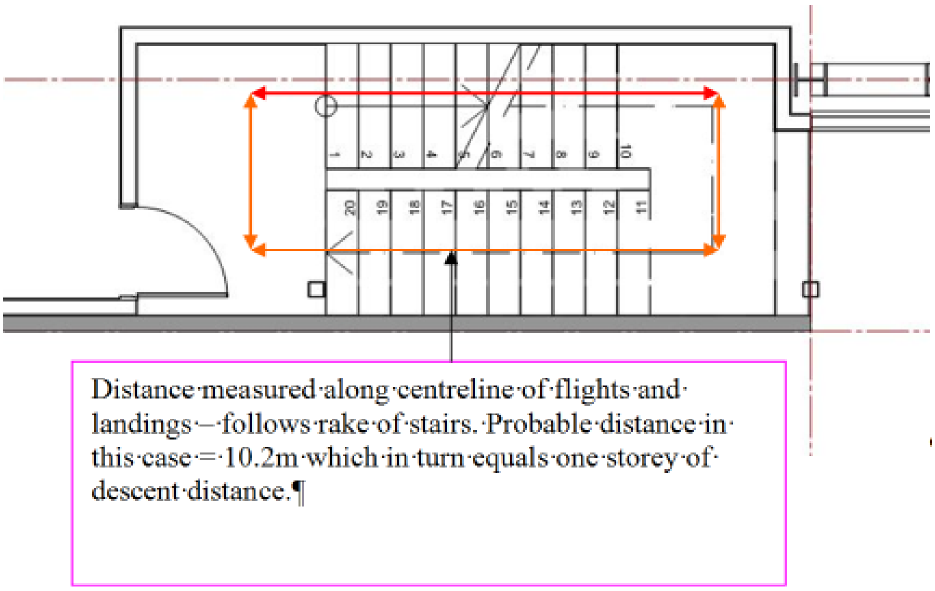


Figure 3-19: Typical dog-leg stair showing how distance is measured between storeys.

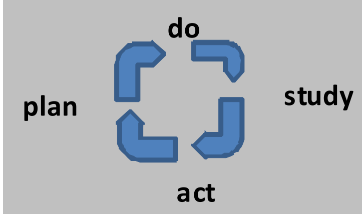
The stair descent chart (Figure 3-18) is a valuable tool for the process of triangulation which is vital for the integration of data gathered by different collection methods (Hales, 2011). Respondents from the survey can be positioned on the chart and their comments related to the apparent contextual factors such as group dynamics and measured distance traversed. Comparisons can be made and "facts" established (as suggested Figure 3-7).

3.7.4 The 2008-2010 Trial Evacuation Survey

Introduction

There was a need to plan the overall case study process for this PhD Study. In order to be flexible and to incorporate feedback from the initial exploratory case study as the first case study and then from the Explanatory case studies, the Plan-Do-Study-Act Cycle[124] (NHS, 2008) was adopted as a means of continually reviewing and improving the operating case study protocols and tools to completely answer the research questions, aim and objectives of the main PhD study. This approach is similar to that used to improve quality and is commonly used in the field of Health and Safety (Roughton and Crutchfield, 2008 and NHS 2008). The elements of the cycle are shown in Figure 3- 20 and explained in the text of the same figure.

[124] PDSA is exactly the same as the PDCA (Plan-Do-Check-Act) used in the process of continuous quality improvement.



Plan – define the detailed questions, objectives (within overall objective in Chapter 1.3.3), and predictions required. Ask the required detailed research questions , plan out data collection methods to answer the research questions.

Do – Carry out the plan, collect the data, begin to analyse it.

Study (Analyse) – Complete the analysis of the data and determine what predictions can be made Summarise what was learned.

Act – Plan the next cycle. Decide whether changes or refinements are required especially where protocols were unsuitable and predictions were not able to be made. List and decide on changes.

Figure 3- 20: Plan Do Study Act Cycle for Improvement through Case Study Process

(Source: NHS 2008)

The PDSA cycle allows for a review of the trial evacuation protocols on the completion of each exercise. A feature of the case study method is that it encourages flexibility (Yin, 2009). Continuous improvement is desirable in terms of improving reliability. This was one of the concerns raised by the Delphi Group regarding the measurement of fitness. The use of self reporting to gather this information was considered to be unreliable especially according to Brener et al, (2003) in a review of the literature on the self reported assessment of health-risk behaviours in adolescents. The measurement of fitness was therefore improved. Another example of the use of the PDSA process was the improvement of the fixing method for the cameras because of the problems experienced with the delamination of the tape due the excessive heat conditions in the stairs during the evacuation of Building M2 (Table 3-9)

Data Collection Tool/ System	PDSA 1 (M1/M2)[125]	PDSA 2 (M3/M4)[125]	PDSA 3 (M5/M6)[125]
Questionnaire	Measurement of fitness by BMI and follow up questionnaire on fatigue	Measurement of fitness by BMI correlated with health conditions with follow up questionnaire dispensed with	Small addition to questionnaire of IPAQ Short Form fitness questionnaire which had been validated
Video camera fixing	Use of heavy industrial tape suitable for attaching objects of less than 1Kg to masonry and plasterboard lined walls.	Replacement of tape fixing method after completion of M2 trial evacuation with flexible grips that could be attached to most handrails and hydrant risers – offered greater flexibility of coverage and remained in place regardless of the amount of vibration and heat.	Retained use of fixing device as shown in Figure 3-17.

Table 3-9: Examples of PDSA Improvements

[125] The pairing of the buildings for each cycle is based on replication logic. PDSA 1 comprises the two buildings at either end of the scale in terms of height. PDSA 2 comprises the third highest and the third lowest with PDSA3 comprising the second highest and second lowest. Thus aggregation of cases is made possible for analysis in Chapter 7 for PDSA1 and 2 together and PDSA 3 on its own in order to compare the fitness reporting method outcomes. PDSA 3 comprise Buildings M5 and M6 which is where the IPAQ based questionnaire was used.

Questionnaire Development

The original NRCC Template questionnaire designed for the 2008-2010 Trial Evacuation survey was used for the occupants of buildings M1 and M2 during PDSA Cycle 1. The original template was added to with a follow up questionnaire administered 24 hours after the completion of the exercise to measure after effects such as lower limb pain in each of the respondents. This addition was as a result of a suggestion by the UK Delphi Group.

On completion of the trial evacuation of building M2 the follow up questionnaire was found to be impractical mainly due to people who had participated in the exercise either not completing the follow-up or being absent when it was handed out. The author reviewed the value that the follow up actually added and it was decided that the follow up questionnaire could be dispensed with. The question could quite well be asked as to what was done to replace it in terms of data collection. It was decided after further research on the measurement of fitness that the answer lay in what affected stair descent performance. Increased BMI for example increased the risk of falling (Menegomi et al, 2009). Combining health conditions together with BMI was seen as being an improved self reporting measure and was adopted for PDSA Cycle 2 without having to change the questionnaire.

On completion of the trial evacuation exercise of M3 and M4 (PDSA Cycle 2) the self reporting measure of fitness was again reviewed. The advice from the UK Delphi Group could not be ignored in that validated fitness self reporting systems were available. Reviewing the “rules” of the case study method (Yin, 2009) and also the opportunity of direct comparisons being made with similar studies associated with occupational tasks such as Steele and Mummery (2003) it was decided to add on the short form International Physical Activity Questionnaire (Sjostrom et al, 2005 and Ottevacre et al, 2011). The resultant questionnaire was used in the survey of trial evacuation participants on buildings M5 and M6 as well as in the focus group studies as these formed parts of the 2008-2010 Case Study Explanatory studies.

Summary of 2008-2010 Questionnaire Content

PDSA 1: NRCC Template and Follow Up (See Appendix A3):

The first questionnaire was derived directly from the NRCC Template (Proulx et al, 2006) and the 1980 Study (available in Appendix A3). The questionnaire is summarised below and is included in Appendix A3:

Section One: While you were on the Floor

The key questions in this section for the study provided the following information:

- Floor of origin on sounding of the alarm.
- The stair used – was it the designated for the respondent's floor.
- Whether or not the stair was the closest.
- Requirement for assistance to evacuate.
- Queuing at stairs with the reason.
- Stair entry with or without a friend and where the group was formed
- **Key question concerning an estimate of the number of storeys the respondent could complete without a rest.**

Section Two: Whilst you were going down the stairs:

The questions were tabulated and related the respondent's self reported experience whilst going down the stairs.

- Handrail reachability
- Step uniformity and visibility.
- Stair steepness
- Tread width
- "Too many flights?" a measure of the total distance traversed as this could be calculated from knowing the floor of origin.

This section of the questionnaire also included questions of their "condition" during descent in terms of pain in the lower limbs, dizziness, and fear of falling, out of breath, chest pains, sore knees and general fatigue. Other questions in this section dealt with the following:

- Level of confidence in descent.
- Conditions in the stairs – i.e. presence or otherwise of others. This question was triangulated with actual density observed on the stairs from cameras and as described by observers.
- Estimate of total evacuation time.

Section Three: About you – self reported intrinsic characteristics.

The details provided were:

- Floor on which they normally worked and check question about floor of origin.
- Check question about stair designation
- Evacuation experience

- Check question about estimate of maximum floors respondent could descend.
- Age, gender, height and mass, and shoe size (to triangulate with tread width).
- Falls history over the previous three years.
- Health conditions – heart, asthma, stroke, diabetes, arthritis in lower limbs, vestibular problems (balance), reduced mobility or injury affecting mobility, reduced hearing and sight, memory loss, multitasking ability, fear of falling, fear of crowds and other including agoraphobia.

Follow up questionnaire.

- Floor location at start of evacuation.
- Level of muscle stiffness.
- Health conditions as before.
- Intrinsic characteristics.
- Falls history as before.
- Questions about level and type of daily exercise and normal use of stairs.
- Normal use of handrails.
- Muscle pain.
- Experience with downhill running.

PDSA 2: Dispensing with Follow Up Questionnaire (See Appendix A3):

This questionnaire is exactly the same as for PDSA 1 except that the following questions were added to replace the follow up questionnaire:

- Level of muscle stiffness
- Questions about level and type of daily exercise and normal use of stairs.
- Normal use of handrails.

- Muscle pain.
- Experience with downhill running

PDSA 3: Adding of short form International Physical Activity Questionnaire (Validated). - See Appendix A3:

Section One of the questionnaire dealt with all the intrinsic details, health conditions and falls history.

Section Two dealt with the actual trial evacuation:

- Designated stair or not?
- Closest stair or not?
- Assistance to evacuate required?
- Queuing at stair and cause?
- Enter the stairs with a friend and where the group was formed?
- Estimate of evacuation ability.
- Stair descent experience and after effects as before.
- Normal use of stairs and level of confidence.
- Conditions in the stairs – crowded or not as before.
- Evacuation time estimate.

Section Three: Short Form IPAQ + Questionnaire

Questions asked about level of exercise undertaken with a predetermined scale and time spent. From this the amount of energy expended in the week could be calculated using the explanatory IPAQ Code. This included a set of questions about the level of exercise seven days before the trial evacuation exercise. The questions also included walking and sedentary behaviour. A section was also included on fatigue.

Survey Analysis

The question dealing with the experience of the respondents going down the stairs and the after effects including the ones associated with distance were seen as providing the main opportunity for factor and additional correlation analysis. The outcome from this analysis could then be triangulated with a similar factor analysis of the data from the physical assessment template. This approach is based on a similar analytical method used in case study of the outdoor stairs (MacLennan et al. 2011). Another example of opportunities for triangulation was between the distribution of shoe sizes on each building and their triangulation with the measured tread widths. The comparison could also be triangulated with stair descent confidence or concern about tread width.

Triangulation (Hales, 2011) is discussed in the next section. Comparison between the observed and survey data may also be found in Appendix A7.6 and also Chapter 7.

3.7.5 2008-2010 Case Study - Triangulation

Read this section in conjunction with Figure 3-21. There are three sets of data for analysis being survey data, participant observer comments and assessment and video image transcriptions:

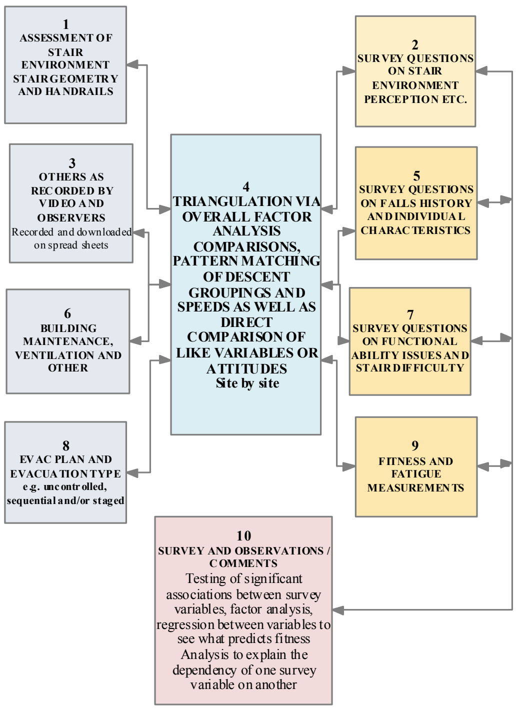


Figure 3-21: Process of Data Analysis and Triangulation

- *Survey based data:*

  (a) Responses re the individual's perception of the stairwell environment, physical response to stair pitch, tread width, handrail use, etc. (BOX 2).

  (b) Falls history and physical characteristics such as age, gender, height, mass, BMI, and foot size. (BOX 5).

(c) Type and number of health conditions/ functional limitations and difficulty with stairs such as dizziness, vertigo, degree of confidence, reaction to others on the stairs, group formation etc. (BOX 7).

(d) Preparing a short structured diary of daily activities over the week before the evacuation which are classified according to the degree of exertion from which a daily METS equivalent could be calculated. This "form" was attached to a modified NRCC questionnaire and comprises a validated survey instrument (Sjostrom et al, 2005) as required by the Delphi Group. (BOX 9)

- *Physical Assessment/ Video and Participant Observer Data*

(a) Physical measurement and recording of details of stair environment via sketch and where possible photographs and where possible coding of resultant data according to a template. (BOX1).

(b) Real time data of individuals descending stairs from which various measurements could be taken in coding for stair descent charts, handrail use, reasons and timing of delays, individuals resting on landings, group formation and dynamics, and other pertinent events. (BOX3).

(c) Building maintenance, ventilation and other – state of the stairs in terms of chipping, marking, stability of handrails, obstructions, defective lighting, pressurisation fans operating (flow of air) etc. (BOX 6).

(d) Evacuation plan and organisation – frequency, extent of participation, preplanning, degree of role play, full or partial completion – coded as series of observations. (BOX 8).

- *Survey and Observer Comments*

  Statistical analysis of data from questionnaires such as frequencies and/or cross tabulation of individual characteristics and then controlling for these characteristics and establishing associations between other variables e.g. BMI and fear of falling, number of health conditions and falls history, number of health conditions and difficulty with stairs. There may also be a need to reduce the number of variables associated with the perception of the stair environment so that they can also be ranked and retested via regression. Stair difficulty or "descent risk" can also be checked against amount of stair use and walking each week as being indicative of the level of fitness. Fitness was recorded in the initial two cycles of case study 2008-2010 prior to being replaced with the more reliable IPAQ form. These relationships were also compared with comments from the observers or person coding the video evidence for the stair descent charts. (BOX 10).

- *Triangulation*

Using the results from the statistical analysis and the associated comments assess impact of stair descent speeds associated with the group that the survey respondent descended with from the video evidence or other findings such as descent capability against stair pitch etc. (BOX 4)

The method of analysis for the case studies are framed by the Delphi Group on one hand in terms of suggesting current issues for questions and observation gathered and filtered via the use of the Ishikawa Chart (Ishikawa, 1982) and on the other hand the results (e.g. factor analysis results of stair use) of the survey are filtered by the focus group using the Ishikawa Chart (Ishikawa, 1982) as a prompt or as a tool to elicit the issues to be considered on each branch on the Chart) against the appropriate grouping. The 2008 – 2010 Case Study was run concurrently with the Focus Groups in order to encourage areas of improvement that could be made in the third cycle of the 2008-2010 Case Study. The design of the possible evacuation tool which could be based on the PhD Study Objective (1.3.3) is based on four basic principles of case study which are:

- Show that the analysis relied on all available evidence.
- Challenge the analysis via the main rival theories e.g. obesity vs. descent speed or obesity vs. fatigue (Galea et al, 2008; Proulx et al, 2007; and Peacock et al, 2009).
- Address the most significant aspect of each case study even if the data presented is in the form of outlier events such as a fall (Pauls, 2011).
- Use the author's prior, expert knowledge and experience to further the analysis as he was immersed in both the exploratory and 2008-2010 case studies.

Finally considering the objective of the PhD Case Study (1.3.3) it is necessary to consider the concept of categorical aggregation (Tellis 1997) as a more comprehensive method of analysis to pattern matching. Multivariate regression is extremely useful when the objective of a study is to test a relationship in the context of many other contextual or explanatory variables as used by Peacock et al (2009) in their study of stair descent. A great deal of the data gathered has been coded into a categorical format so that some form of categorical aggregation may be required. Further reading and comparison of examples put forward by Liang et al, (1992) show that certain forms of Logistic Regression[126] if properly constructed can provide results that are comparable with the Multivariate approach (Miles and Shelvin, 2001).

3.8 Ethical Approval

Ethical Approval was given on 27th November 2008 by the Research Governance and Ethics Sub-Committee for the conduct of Delphi Group and Focus Group meetings. The reference is RGEC 08/008.

3.9 Conclusions

The author has participated in stair-use research since 1979 and therefore needed to re-clarify his research position so as to avoid building on "assumed knowledge" (what you think you know). Crotty (1998) assisted in this regard by stating that there is inter relationship between the researcher and the methods used. Further reading of Gray (2009) showed the author leans towards meaning being constructed .i.e. constructivism. Working through the elements of the Research Process methodology appeared to be the main research driver. The author's position on the continuum is shown in Figure 3-3 where he uses the mixed methods (Amaratunga et al, 2002) and a case study process where mixed methods are encouraged (Yin, 2009) to deliver the aim and objectives of the PhD Case Study. According to Gray (2009) there is no conflict between a constructivist stance and the adoption of a case study approach where mixed methods are advocated.

Previous egress type studies have not clarified the research process so that often rich data can be lost due to the data collection and analytical methods adopted where if a positivist perspective requires that the observer is required to remain independent from the study so that proper deductive analysis of "unbiased" data can occur. Blair (2010) in her analysis from data provided by

[126] Packages available in SPSS V16 e.g. Binary and Ordinal Methods.

Averill et al (2005) found that the data was extremely “noisy” (so that some rich data may have been lost). Interpretivism would be extremely important here as shown by Gray so that the method developed needed to be able to explore the “noisy” data. It can be concluded that mixed research methods or a pluralist approach is the most appropriate (Amaratunga et al, 2002). Interpretivism on the phenomenological side of the paradigm involves qualitative method (focus group and content analysis). Such method(s) needs to be blended with a quantitative method so that the outcome of the quantitative analysis could be placed in context. The one set of results is “enhanced” by qualitative consensus or observations.

The final method selected and described was that of Case Study where the process was designed to fit with the position of the observer and also to assist him in learning by focusing on the individual within the context of others on the stairs, the stair environment and the management/ maintenance of those stairs and its users. Case study method and process is shown to be rigorous by Flyvbjerg et al (2006) and its adoption as the research method in this PhD Study sets it apart from others. The process needed to be designed in accordance with the central direction shown by Gray (2004) in Figure 3-6 and the order recommended by Yin (2009). Such a process is summarised in Figure 3- 5 and Figure 3-8 and fully described in this Chapter.

The exemplar buildings extracted as being representative of Buildings 1-8 in the Exploratory Case Study from the 1980 dataset as well as those forming part of the 2008 – 2010 Case Study are fully described in Chapter 4 following on from this Chapter. The inclusion of the Exemplar Buildings (Buildings 3 and 7) in parts of the 2008-2010 Case Study are used for the longitudinal comparison of case outcomes dealing such relationships as fatigue and distance and expansion of measured stair examples for inclusion in the factor analysis.

Chapter 4 - Case Study Particulars

4.1 Introduction

This Chapter presents the following case study details:

- Exploratory Case Study building particulars and available data
- 2008 – 2010 Case Study building particulars and trial evacuation particulars.

This chapter should be read in conjunction with Chapter 3 – Research Methods

The Exploratory case study comprises eight buildings varying in height from 7 to 45 stories. The buildings were selected by an expert group that included Pauls who was responsible for a series of trial evacuation studies in the 1970's (Pauls 1974) for the National Research Council of Canada. The range was defined as follows:

- By definition of "high rise" in the original building regulations as being those with an internal height measured between the lowest level of final exit and the top most floor level. This was 25 metres and is basically equivalent to 7 storeys of 3600mm per storey.
- The upper limit was defined by the maximum height that could be safely evacuated from the floor of work origin to ground level. "Safety" in this instance was defined by the building owners in terms of the risk that they were prepared to accept.
- Eight buildings in total allowed for a suitable range between 7 and 45 as indicated by the average height of 21 storeys

Each of the buildings are described in this chapter and the range of heights and associated building numbers are shown in Figure 4-1 below:

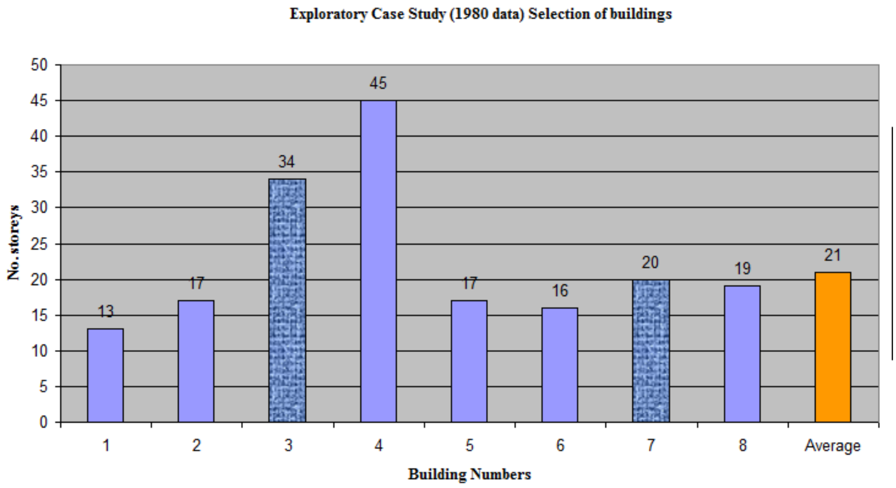


Figure 4-1: Range of building heights for the Exploratory case study (See also table below)

Building No.	Number Storeys	Evacuation Time (mins.)	Evacuation Strategy	Sample Size
1	13	35	Sequential with runners	114
2	17	40	Uncontrolled/ EWIS†	111
3	34	33	Uncontrolled/ EWIS††	138
4	45	35	Partial: Floors 41-45/ 17-21 Sequential†	88
5	7	10*	Uncontrolled†	38
6	16	18	Uncontrolled†	75
7	20	30	Sequential†*	93
8	19	29	Sequential / electronic switching	76

** Descent speed less than 0.35m/s for entire stair for first few minutes due to person on crutches*
† Emergency Warning and Intercommunication System
††Intercommunication portion was on a separate system
† Speakers on some floors were faulty and occupants had difficulty knowing what instructions they were required to follow*
[yellow box] Exemplar building numbers 3 and 7 that are representative of the eight buildings and are included in the 2008-2010 case study

The buildings for the 2008-2010 case study (see Figure 4-2) needed to achieve an average height of approximately 25 storeys as this was the height that 50% of the exploratory case study population estimated they could cope with without a rest and therefore was appropriate to support a longitudinal comparison between two data sets.

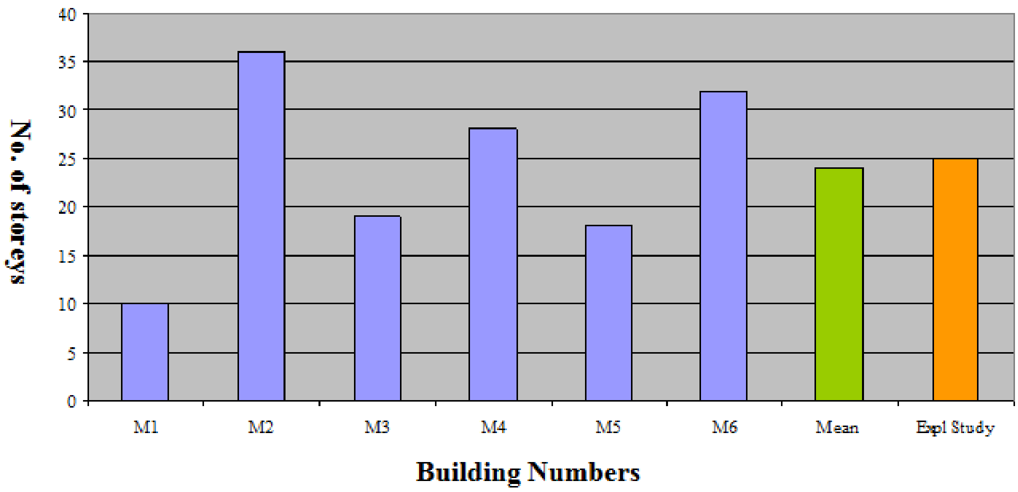


Figure 4-2: Range of building heights for 2008-2010 case study

The lower part of the range was 10 storeys and the uppermost was 36 storeys being the maximum that building owners were prepared to accept for total evacuation of all the occupants in a trial evacuation. As can be seen the building owners appear to have become more risk averse over the last 30 years. This perhaps reflects the concerns of some of the 1970 pedestrian dynamics researchers (Pauls, Fruin and Zupan, 2007) concerning the reduced fitness of the global population. The average building height was 24 storeys which was considered to be a reasonable compromise (compare green and orange columns in Figure 4-2). The selection is described in more detail in a subsequent subsection.

4.1.1 Generally

The linkage between the Case Studies is shown in Figure 4-3 below:

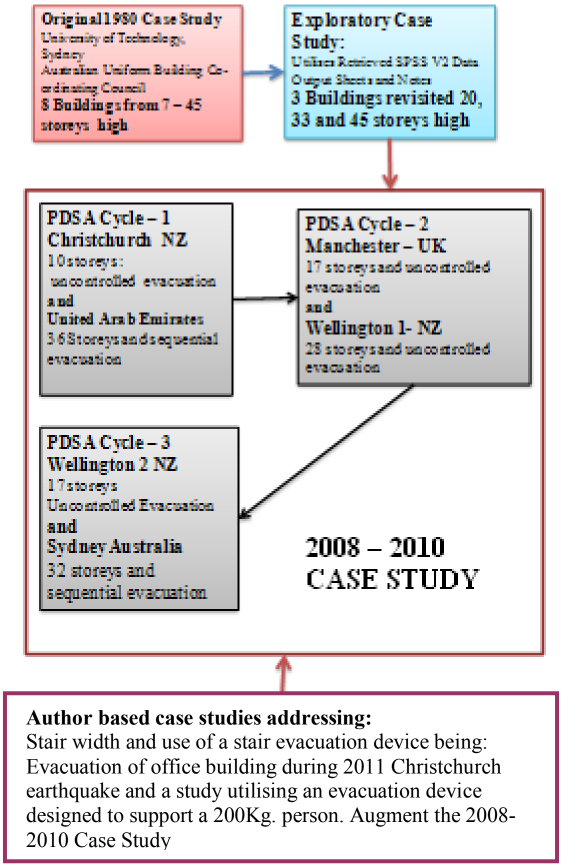


Figure 4-3: Linkage of Case Studies Comprising the PhD Case Study (1980-2010)

Figure 4-3 shows the 1980 Case Study (now the Exploratory Case Study[127]) in light red box which comprised a total of eight high rise buildings located in the capital cities of each state located on the Southern and Eastern seaboards of Australia. The data from the 1980 Case Study undertaken by the Author as a researcher in the School of Building Studies at the University of Technology, Sydney comprised a series of hard copy SPSS V2 Printouts which were revisited and data extracted. These data were sorted and the relevant results are set out in Chapter 5. The 2008 – 2010 Case Study comprises a total of 6 high rise buildings where trial evacuations were held using the same protocols and different survey criteria developed using the Plan-Do-Study-Act process (NHS, 2008). There were three cycles involved described in Chapter 3. The range of buildings for the 2008-2010 Case Study was established from the Exploratory Case Study from which the most common evacuation height that occupants could cope with was established as 25 storeys (MacLennan et al, 2008).

Two of the buildings from the 1980 Case Study that were selected as representative exemplar buildings[128] were revisited in 2010 and the stairs re-measured. One of the other buildings was checked via the author's contacts to confirm the original measurements. This rechecking was seen as being crucial so that the buildings checked for the Exploratory Case Study contained 20 and 34 storeys respectively. The selection of this range was once again based on one of the original findings concerning evacuation height or distance (MacLennan et al, 2008).

[127] There are eight buildings in the Exploratory case study taken from the 1980 Study. From these eight buildings two representative buildings Numbers 3 and 7 are taken as being representative of the Exploraory case study for inclusion in the 2008-2010 case study

[128] Building 7 was 20 storeys in height and Building 3 34 storeys. These two heights and the building details together with the original occupant responses to the survey questionnaire included in Appendix A3

4.1.2 General Building Selection Criteria for Exploratory and 2008-2010 case studies.

Overall the criterion for the selection of suitable office buildings was established in the Author's 1980's Research Project by the associated expert project group. The same criterion was used by the author in the selection of buildings in the in the 2008-2010 case study were as follows:

- Evacuation height > 25m
- Two enclosed fire stairs
- Evacuation plan, programme and regular drills
- Evacuation organisation and policy for those whose functional abilities or limitations precluded them from using the stairs
- Used as office buildings
- Author permitted to attend Warden debriefing sessions
- Building Owners/ Facility Managers permitting the research team to use pre-established trial evacuation recording and observation protocols for the occupants descending the stairs.
- Building Owners/ Facility Managers permitting the research team to use pre-designed questionnaires as part of a required survey of trial evacuation participants or occupants.
- Suitability of the stair layout and location of handrails to permit the fixing of video cameras and also to provide a range of configurations that could be studied to assess their impact on occupant performance.

4.1.3 Structure of Chapter 4

The subsequent sections comprise:

- Section 4.2 - 1980 and Exploratory Case Study
- Section 4.3 – Christchurch Earthquake Case Study
- Section 4.4 – 2008 – 2010 Case Study
- Section 4.5 – Conclusion

Chapter 4 should be read in conjunction with Chapter 3 – Research Methods. It should also be noted that each of the trial evacuation drills in the Exploratory case study buildings and those from the 2008-2010 Trial Evacuation study will be summarised in this chapter together with a description of their layout and construction.

4.2 The 1980 – Exploratory Case Study

The 1980 Case Study comprised a total of 8 buildings as follows as shown in Figure 4-1[127]. The general particulars are described in the table associated with Figure 4-1.

4.2.1 Adelaide, South Australia

Building 5 – 7 storeys:

Building Details

Building five was a seven storey office building hidden behind a heritage type façade (Figure 4-4). A typical floor plan is shown in Figure 4-5. Each level is served with two fully enclosed fire stairs both of which were used during the trial evacuation. They both discharged directly to open space outside the building footprint. The position of the sandstone heritage façade is shown on the plan in Figure 4-5. The building was occupied by a Government Department where occupational health and safety was extremely important. The only additional available information from the records is the clear width of the stairs (1020mm) and the step geometry (tread width of 250mm and riser height of 190mm).

Figure 4-4: Adelaide Building Five – Exploratory Case Study

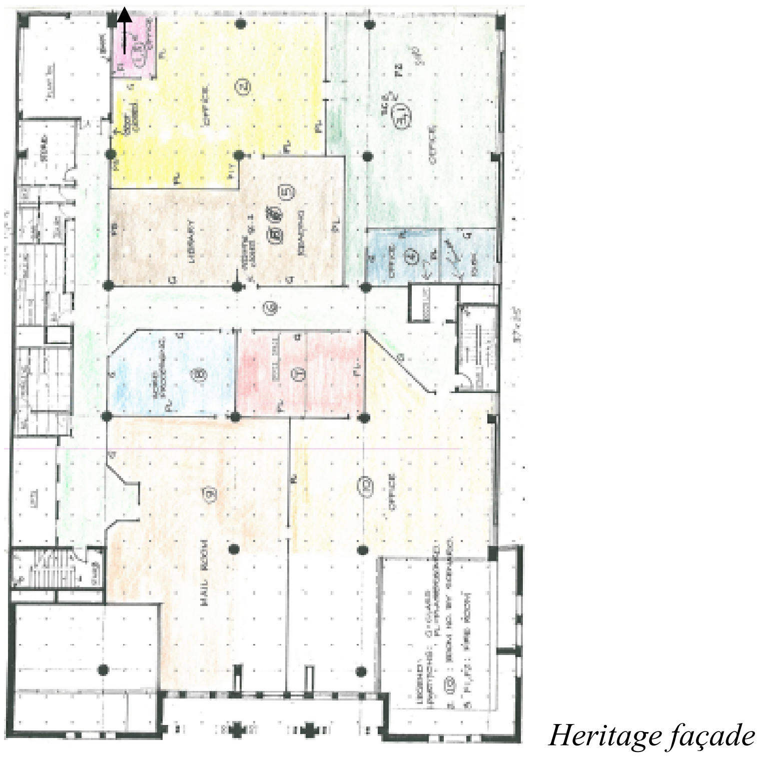


Figure 4-5: Typical Floor Plan of Building No. 5

Trial Evacuation Exercise

The evacuation strategy was simple uncontrolled evacuation sequence where every floor was permitted to enter the stair as instructed by their fire warden on the sounding of the alarm. The total evacuation time was 10 minutes with the extended time resulting from delays caused by a person on crutches. According to records there was one observer on level 3, 5 and 7. Each one of the observers had a Dictaphone and collar microphone. They noted the time the first person entered the stairs "sounding" letter "p" for males and "q" for women. Thus the entry sequence on levels was therefore a series of "p's" and "q's" sounded out at the exact interval the person concerned crossed the door threshold into the stairs The 4th floor represented the simulated fire floor and each entrance to the stair on that level was covered by a video camera. The Dictaphone cassette tapes were abstracted on to an observation log. Questionnaires were handed out at the final exit to each of the stairs. The questionnaires were numbered and therefore could be used to create an accurate exiting profile including the floor number the individual started from together with all their other responses on the stairs. The observer was always the last person to enter the stairs from their level of responsibility. The data could then be used to reconstruct a stair descent chart from the exit and entry times similar to the example for Building 6.

The alarm was sounded throughout the building a single signal and people responded randomly. The total evacuation time for the entire building was some ten minutes.

One interesting occupant that need to be catered for during the event was a male person crutches on Level 4. He insisted on using the stairs and the floor warden required this person to enter the stairs ahead of all the others. He delayed and "annoyed" other colleagues behind him.

Building 6: 16 storey building

Building Details

Building six (Figure 4-6) was originally occupied by a major bank as the major corporate tenant. Health and safety was extremely important and regular trial evacuation drills were held. A part typical floor plan is included as Figure 4-7 below. The building has two fire stairs which discharge direct to open space outside the building footprint. The stair treads were 280mm wide and the risers 180mm high. A single handrail was provided and there was a reasonable contrast between the walls, stairs and handrail. The shaft was provided with emergency lighting.

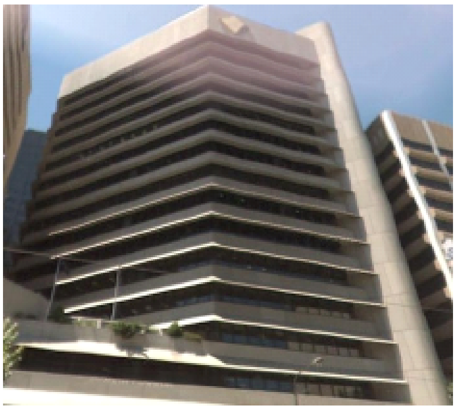


Figure 4-6: Adelaide Building Six - Exploratory Case Study

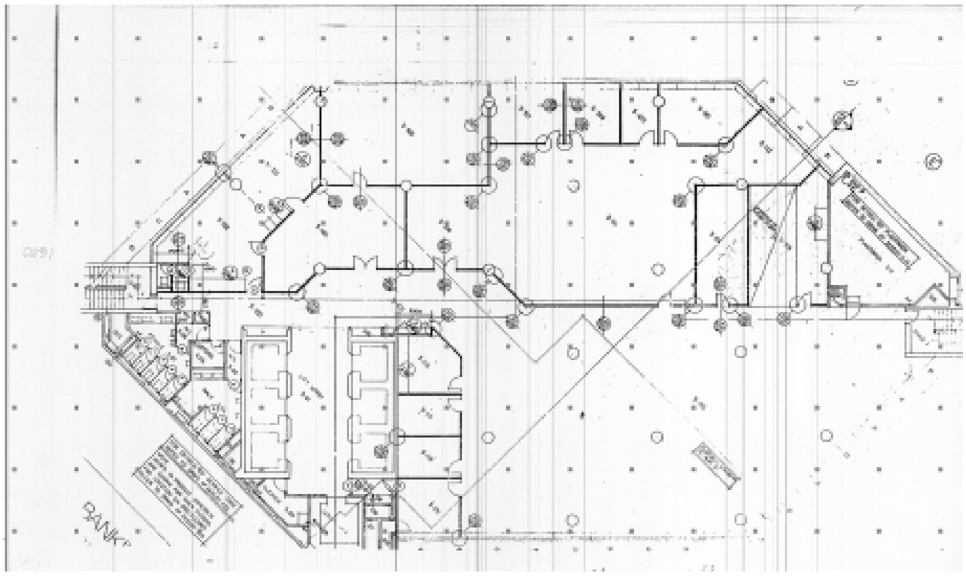


Figure 4-7: Adelaide Building Six – Part typical floor plan

Trial Evacuation Exercise:

The building was provided with an emergency warning and intercommunication system. Although the procedures were centred on a sequential or controlled procedure the operation of the emergency communication panel was faulty on the day of the evacuation[129] so that the procedure reverted to an uncontrolled evacuation when handed over to the floor wardens via a central announcement via the intercom to all the levels. The exercise therefore did not follow the written evacuation procedures but the training was such that the floor wardens took over. They reported to the chief warden outside the building on completion that their floor was clear and that everyone was out of the building. The alarm comprised an alert tone followed 30 seconds later by the evacuation tone. Occupants commenced started to move randomly and followed the instructions of the wardens. Wardens were positioned in accordance with the written evacuation procedures including wardens located at the entry to each stair.

[129] Confirmed post evacuation by the Chief Fire Warden.

From available records there were observers located on levels 16 and 15, 12 and 11 and 3 and 2. Stairs were designated for set levels. Data was collected by video cameras and observers with questionnaires being handed out at the final exit from each stair. The exact positions of the cameras are unavailable because of insufficient records. A stair descent chart reconstructed from these data at the time was available and has been included for one of the fire stairs illustrating the random entry sequence. The evacuation time was 18 minutes

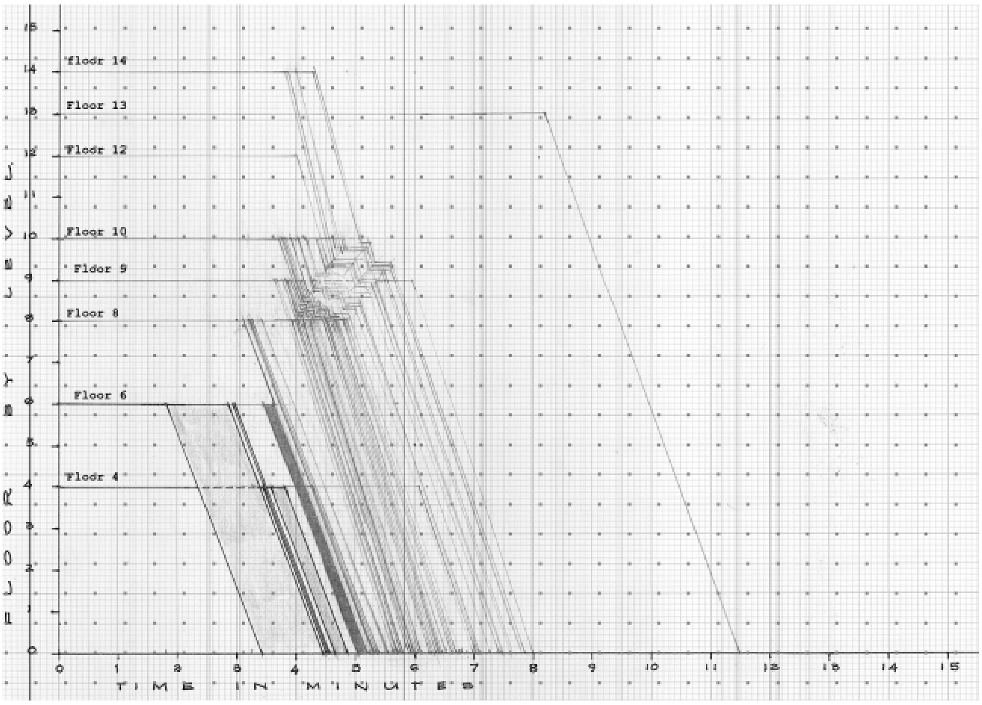


Figure 4-8: Example of stair descent chart for Building 6 – Entry sequence

4.2.2 Melbourne, Victoria

Building 4: 45 storey office building

Building Details

Building four was occupied by multiple tenants most likely with a similar profile to Towers 1 and 2 of the WTC. A typical floor plan is included for reference in Figure 4-10 below. The building had two enclosed fire stairs that discharged at ground level, one into the ground floor lobby and the other outside.

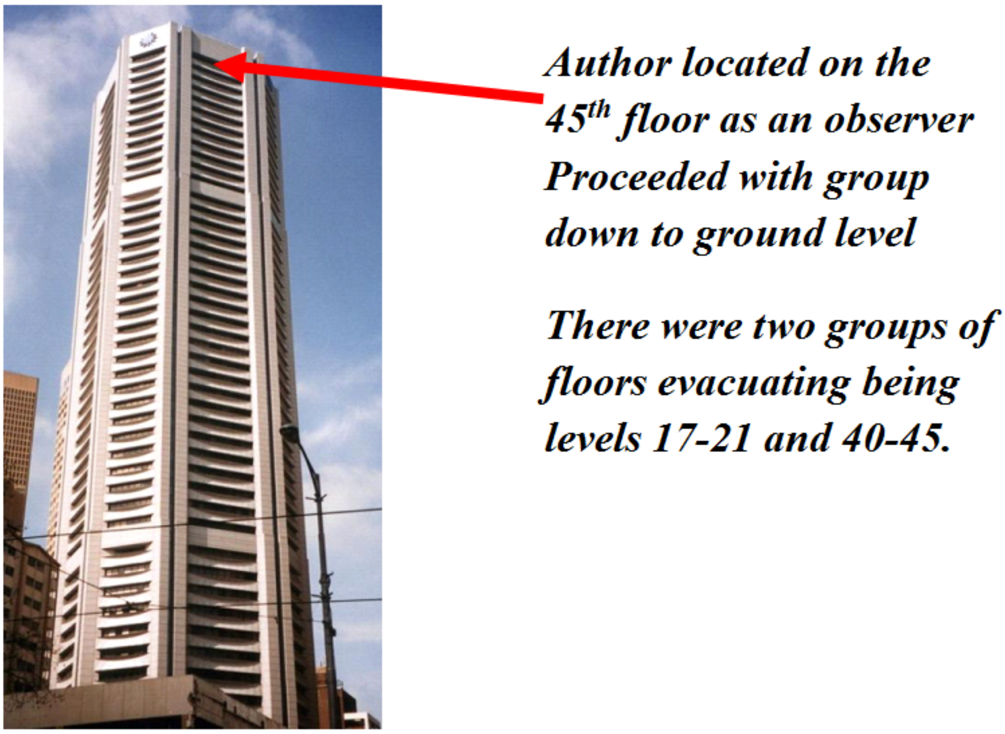


Figure 4-9: Building Four Exploratory Case Study

The stair treads were approximately 250-260mm wide and the risers 180-190mm high. The clear width of the stairs was 1020mm. There was little contrast between the walls and stairs and a single handrail was available. The shaft was provided with emergency lighting and was pressurised. The building was provided with an automatic emergency warning and intercommunication system and the evacuation strategy was for a phased evacuation the pattern of which was sequenced in accordance with the location of a fire or incident.

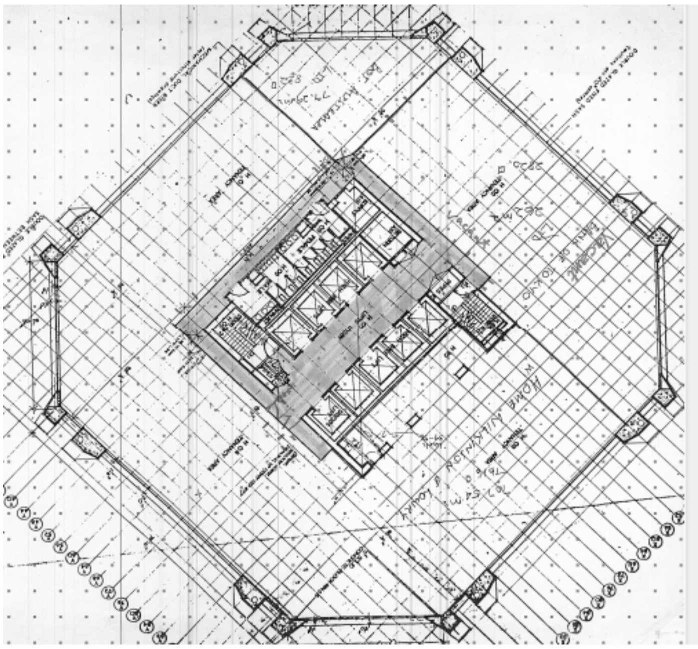


Figure 4-10: Typical Floor Plan for Building 4

Trial Evacuation Exercise

The Authorities would not permit the drill to cover the entire building so that the drill covered two parts of the building being five mid-level floors and five upper level floors with the uppermost level being the top floor of the building. This sequence selected for the trial evacuation was proposed by the building owner and Authorities to line up with the phased evacuation pattern. Floors were generally evacuated five floors at a time. This represented the incident floor with two floors above and two floors below. The owner permitted a double grouping for the trial and suggested that this pattern was used for training as well. The upper group of floors comprised floors 41-45 and the lower 17 – 21. One stair was designated for the high rise and the other for the lower group as per the evacuation procedures. The author was an observer on Level 45 and he had a BMI of 52 at that time. Observers were positioned on Levels 45, 43 and 41 and Levels 21, 19, and 17 on the lower group. Video cameras were located on the incident floor being level 42 in the upper group and 18 in the lower group. Numbered questionnaires were handed out at the final exits from each of the fire stairs. Both groups of floors evacuated simultaneously on the sounding of the evacuation alarm which was clearly audible. Prior to entering the stairs the evacuation plan called for the warden to check for all the occupants prior to anyone entering the stair. When the occupants did enter the stair they entered as an entire group in quick succession lead and followed by wardens. The groups were quite large. The evacuation time for the upper group of floors was some 35 minutes with one of the occupants falling most likely due to agoraphobia (NCIM, 2012). Data was collected as before from the observers' Dictaphone tapes and the returned questionnaires and analysed. Stair descent charts were reconstructed from the analysis.

Building Two: 17 storey office building

Building Details

Building Two is a 17 storey office building with three fire stairs, one discharging inside the ground floor lobby and the other two direct to the outside. There was a single corporate tenant comprising a major bank in Building 2 (Figure 4-11). A typical floor plan is shown in Figure 4-12. The stairs are grouped with the lifts and were all pressurised and provided with emergency lighting.

Figure 4-11: Building Two - Exploratory Case Study.

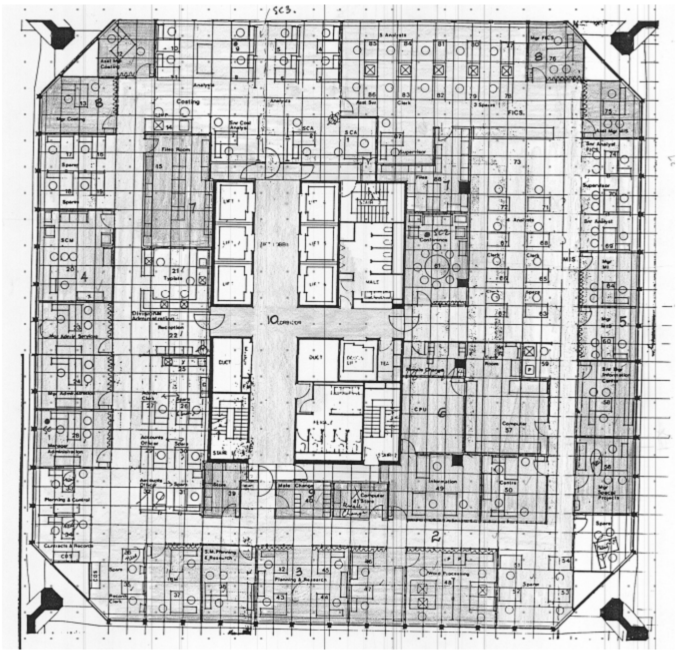


Figure 4-12: Typical floor plan Building 2

The stairs according to previous notes comprise reinforced concrete construction with 250mm treads and 190mm risers and had a clear width of 1020mm. Stair entry doors were 1000mm wide and encroached on to the clear width of the stairs at each major landing. There was a single handrail in each stair. There was sufficient space on the main landing on each level for occupants to rest.

Trial Evacuation Exercise

The evacuation strategy was for sequential evacuation utilising an automatic warning and intercommunication system. Phased evacuations were also possible. Evacuation commenced from the top floor with the next floor following on once the upper floor was cleared. Only two of the stairs were monitored for this exercise because of resourcing. Observers were positioned on Level 17, 12, and 3. They were provided with Dictaphones which were also supplied to some wardens. The additional wardens were briefed on observation protocols before the exercise commenced. The overall evacuation time was approximately 40 minutes before of the delays caused by the response patterns on the upper levels. Questionnaires were handed out at the final exits of the two monitored stairs. Data was obtained from the questionnaires and observer tapes and analysed as before. Stair descent charts were reconstructed from the data which emphasised impact of the upper floor delays. The most interesting feature of this evacuation drill was that some of the occupants on the lower floors took over 30 minutes to gain access to the stairs because they continually deferred to occupants from above.

4.2.3 Sydney, New South Wales

Building One: 13 storey office building

Building One (Figure 4-13 and Figure 4-14) was originally occupied by a single government department tenant. Five of the levels were used for car parking with the upper eight floors as office space. Stairs were approximately 1020mm in clear width, 250mm wide treads and 190mm high risers. There was a single handrail. The walls were grey along with the stairs. Both stairs discharged direct to the outside of the building. Emergency lighting was provided but the stairs were not pressurised.

Figure 4-13: Building One - Exploratory Case Study

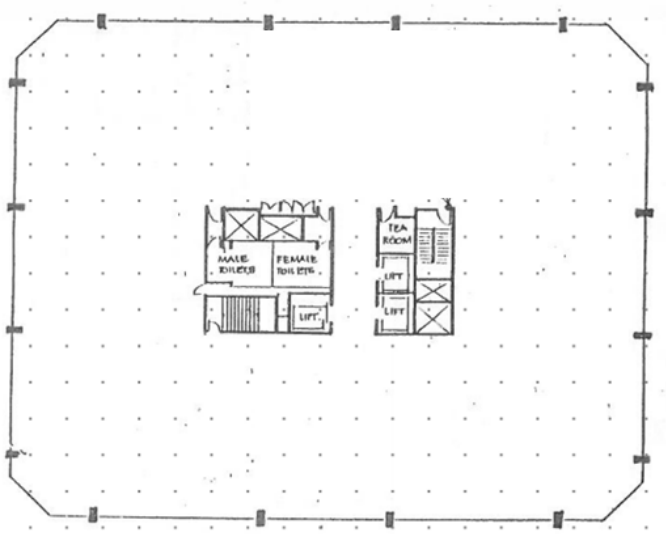


Figure 4-14: Typical floor plan Building 1

Trial Evacuation Exercise

There was no emergency warning and intercommunication system installed in the building. Management were still committed to health and safety so that trial evacuations were triggered via manual communication comprising a pre-planned telephone network and runners between floors. The runners warned the next floor above of the incident and to evacuate. This was repeated for all eight levels. The evacuation drill therefore resembled a sequential evacuation as the floors were notified in a set sequence for commencement of the drill.

On the day of the exercise level 8 was selected as the fire floor. Observers were positioned on levels 13, 10 and 8 for each stair. The observers were provided with Dictaphones and lapel microphones. Observation protocols were as before. Some counter flow was introduced with fire-fighters gaining access at ground level and ascending to the simulated 'fire floor' which was level eight. Numbered questionnaires were handed out at the final exit from each stair. Data was gathered from the returned questionnaires and observer Dictaphone tapes and analysed. A stair descent chart was reconstructed showing the delay in entries between each level. This explains the overall evacuation time of 35 minutes.

Building Eight 19 storey office building

Building Details

Building eight (Figure 4-15) was originally occupied by one major tenant, being a major banking organisation. A floor plan is included in Figure 4-16. The building contained two fire stairs in opposite corners of the building which discharged directly to the outside. One of the stairs is connected to the lift lobby. Treads measured 250mm and the risers 190mm.The clear width of the stairs was 1020mm. The walls and stairs were grey with no contrast between the walls and stairs. Support was provided by a single handrail in each stair. The stairs were pressurised and provided with emergency lighting. The automatic fire alarm only notified the emergency management team and fire brigade. The building was provided with a manually operated alarm and inter-communication system.

Figure 4-15: Building Eight - Exploratory Case Study

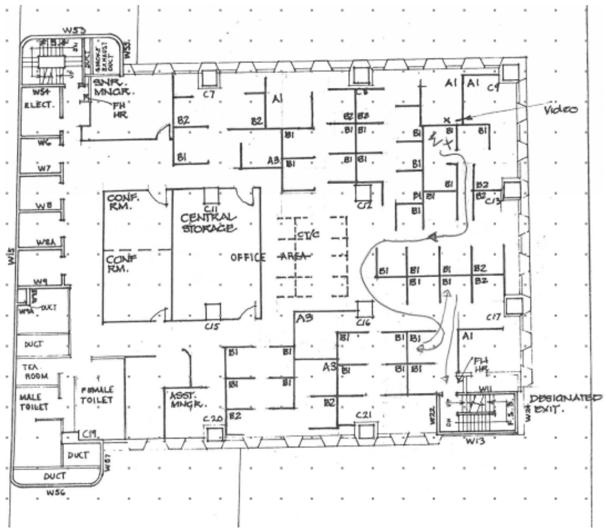


Figure 4-16: Floor plan of Level 18, Building 8. (Marked up with an occupant's movement path from original project).

Trial Evacuation Exercise

The management were committed to health and safety. The chief fire warden initiated the alarm for the exercise manually from a control console comprising a series of toggle switches, one for each floor. He evacuated the floor in groups of five starting at level 19 and then in descending order. Observers were located on levels 19, 11 and 3. The video camera was located on the "incident" floor and recorded the flow of occupants from that floor into the exits. The observers were provided with Dictaphones and lapel microphones. Numbered questionnaires were handed out at the final exits from each stair. Data was gathered from the returned questionnaires and the Dictaphone tapes. These data were analysed and a stair descent chart reconstructed showing an overall evacuation time of 29 minutes.

4.2.4 Brisbane, Queensland (Exploratory Case Study Exemplar Buildings for 2008-2010 case study)

As noted in Chapter 4 after attempting to gain access to Buildings 1-8 from the Exploratory case study the only access that was available was to Buildings 3 and 7 each of which are located in Brisbane. They also most closely resemble the layouts and protocols associated with their use in the 1980's. They are representative of the sample in terms of height and layout. This was also confirmed by the response of occupants of the maximum number of storeys they thought they could descend without a rest. 50% of the population responded that 25 storeys was the limit, Building 3 is 33 storeys and Building 7 is 20 storeys. The meaning of exemplar in this regard is representative. These buildings can therefore be studied further in the 2008-2010 case study for longitudinal comparisons and factor analysis.

Building 3: 33 storey office building

Building Details

Building three in Brisbane is a thirty three storey office building located in the Brisbane CBD. It has been refurbished in part since the 1980 trial evacuation was held but the stairs are the same and reasonably well maintained.

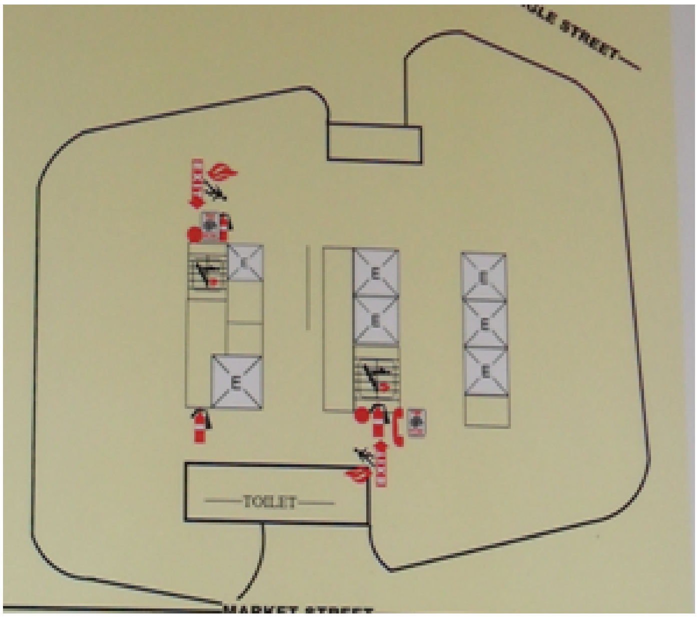


Figure 4-17: Diagrammatic Floor Plan for Building Three – Exploratory Case Study.

Figure 4-18: Typical View of first stair flight at stair entry – Building 3 – Exploratory Case Study

The building was re-visited in March 2010 and the following observations recorded:

- The emergency warning and intercommunication system had not been totally upgraded since the 1980's.

- The stair is much the same as Building 7 except there is a lack of uniformity in risers on many of the flights up to +/- 10mm.
- Floor numbers are well signposted in red on each level.
- The level of illumination is good with a fluorescent fittings of increased output compared to Building 7. There is only a minimum amount of shadows cast across some of the steps in each flight.
- There is no marking on the nosings so the steps are not really legible (lack of edge conspicuity).
- The stairs serve 32 levels with low rise classified as 1-13 and high rise as 15-32. Both stairs open off the lift lobby.
- The handrails are not graspable being made from a 75mm deep by 15/20mm thick steel flat.
- Handrails are painted black so that there is some contrast with the cream coloured walls.
- The stairs are steel trowelled finish so that there is some edge contrast with the walls.
- The fire hydrant outlet does not obstruct the movement or circulation path.
- The handrail section does not act as a balustrade so that there is a completely open void.
- Treads are 250mm wide approximately and risers 190mm high. Stairs have a clear width of 1020mm.

There are additional visual images in Appendix A4 that amplify the above observations.

Trial Evacuation Exercise

The building was equipped with an emergency warning system supplemented by a mobile intercommunication system. The chief warden and floor wardens were supplied with these devices. The procedures called for an uncontrolled evacuation where all occupants evacuated on the sound of the evacuation signal. Wardens were positioned at the entry to the stairs to provide assistance where necessary.

Observers were positioned on Levels 33, 26. 19 and 10 and the video camera on level 8 which was set as the incident floor. Questionnaires were handed out at the final exits from each of the stairs Data was gathered from the returned questionnaires and observer Dictaphone tapes and analysed. As before a stair descent chart was reconstructed. The evacuation went extremely smoothly, the overall evacuation time being 33 minutes.

Building 7: 20 storey office building

Building Details

Building seven in Brisbane is a twenty storey office building located in the Brisbane CBD. It has been refurbished in part since the 1980 Research Project trial evacuation was held but the stairs are the same and reasonably well maintained.

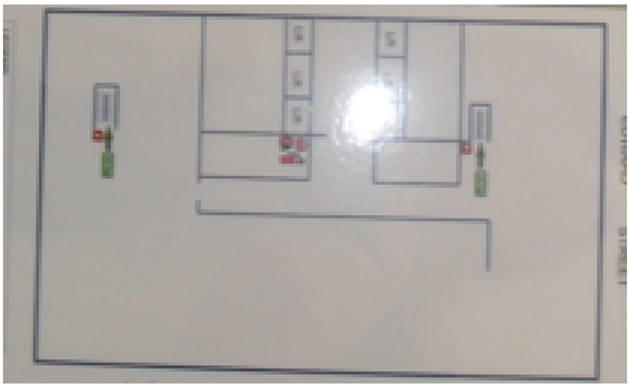


Figure 4-19: **Building Seven Brisbane Typical Floor Plan serving as part of signpost in Lift Lobby**

Figure 4-20: Typical view of down flight approaching entry door – Building 7 (*other stair is opposite handed)*

The following observations were made from the original survey and from the revisit in March 2010:

- Occupants are firms of Engineers, Insurance Brokers, Government Agencies and Financial Institutions.
- The building has been refurbished but the stairs remain much the same in terms of handrails (rectangular section – poor graspability), steel trowelled finished steps and landings, wall colours, internal hydrants (possible obstruction), degree of illumination, lack of nosing conspicuity,

- There is no legibility between the steps (grey on grey). The handrails are not graspable because of their 30X30 rectangular shape and position of supports.
- Large amount of shadows on steps even although there is a fluorescent light at every level and mid landings.
- There are floor level number signs on the internal face of the fire doors but they are not consistent and some are not readily visible.
- One of the fire stairs discharges into the main lobby on the ground floor whilst the other discharges directly to the outside.
- There is only one handrail and the void is quite large so people with vertigo may have problems.
- Stairs were well maintained and clean.
- Stairs are opposite handed to each other.
- Treads are 250mm wide approximately and risers 190mm high. Stairs have a clear width of 1020mm.

Additional visual images are available in Appendix A4 that provide further information about the above bullet points. The completed stair assessment template is included in Appendix A4.

Trial Evacuation Exercise

The building was equipped with an emergency intercommunication system and the strategy basically sequential. The procedure required wardens on each floor to be at their communication points after the sounding of the alert signal. There was confusion at this point on the day of the exercise because the announcements made on the floors were inaudible. Wardens were unclear as to what they were required to do so that in many instances the floor wardens took over and some started to evacuate before the evacuation signal was sounded.

Observers were positioned with their Dictaphones and lapel microphones on levels 20, 15, 10 and 5. Numbered questionnaires were handed out at the final exit from each of the two stairs. Data was gathered from the returned questionnaires and observer Dictaphone tapes. Stair descent charts were reconstructed and showed the impact of the communication problems. The overall evacuation time was 29 minutes.

4.3 Author based case studies

See link to 2008-2010 case study in Figure 4-3. There are two case studies involved being:

- The Christchurch Earthquake evacuation focussing on the stair width dichotomy.
- The assisted evacuation testing an evacuation device and its performance in terms of descent speed as an extension of the study by Adams and Galea (2010).

4.3.1 Christchurch Earthquake Evacuation

This case study addresses the minimum stair width dichotomy where recommendations have been made to increase the widths to between 1200mm and 1500mm (Peacock et al, 2009 and Pauls et al, 2007). The author at the time was unable to descend the stairs without the use of both handrails because he was morbidly obese, had a fear of falling and severed pain in his lower limbs.

On the 22nd February 2011 at 12.51.42pm (epicentre) Christchurch experienced a magnitude 6.3 Earthquake which resulted in extensive damage to two of the office buildings in the Central Business District. Two multi storey office buildings actually collapsed being the Pyne Gould Guiness Building (Figure 4-21) and the Canterbury TV Building (Figure 4-22) in the centre of the city. The author was located on the fifth level of an 8 storey office building at 123 Victoria Street (see Figure 4-23) at the time of the earthquake. The location is within 1000m of the centre of the city.

Figure 4-21: Pyne Gould Guinness Office Building

Figure 4-22: CTV Building Total Collapse

After the initial shaking had subsided the whole building was required to evacuate to a safe place away from the building. The building had extensive damage so that occupants were not permitted to return into the building for quite some time.

Figure 4-23: 123 Victoria Street - Author's Location

Figure 4-24:- Partial View of Main Fire Stair 123 Victoria Street

Figure 4-24 shows a view of the stairs some time after the earthquake when some of the occupants were permitted in the company of a certified structural engineer to retrieve some of their equipment out of the building (duration of stay not greater than 60 minutes). Some of the stair flights were not fully secured between landings and this represented the condition on the day of the earthquake.

The details of the stairs were as follows:

- Two handrails provided which were about 40mm diameter and readily graspable.
- Tread width was >260mm and riser height approximately 180mm.with a pitch in percentage terms of 68%.
- The handrails and steps were reasonably legible
- The level of illumination was > 50 lux
- The width was about 1000mm
- There were two turns per storey with the stair being a dog leg stair.
- There were no substantial obstructions
- The stair did not discharge directly to the outside so that occupants needed to be familiar with the exit route.

The shaking of the ground and building commenced at 12.51.42. The occupants commenced evacuation at approximately 12.52pm. It is estimated from interviews conducted with the floor fire warden that the first person from the author's level took some 30 seconds to exit the building. The opening descent speed was approximately 1.2m/sec.

The author as part of a group formed at the work location entered the stairs at approximately 12.54pm. He took some 80 seconds to exit the building. In so doing he held up the rest of the group and would have fallen if there had not been two handrails provided.

The stair was constructed of "L" shaped precast concrete sections supported on a steel framework. The latter was damaged during the quake. Water from the domestic water supply "poured" down the entire well so that surfaces were slippery. Lighting remained intact and the evacuation alarms sounded for the entire duration of the evacuation.

The results of the case study are discussed in Chapter 7.

4.3.2 Author Case Study – Assisted evacuation on stairs

The following case study is where the author, as an expert immersed in the PhD Case Study, challenged the findings of Adam and Galea (2011) and Zmud (2007) and carried out his own site test where the mass of the individual requiring assistance was some 200Kg.

The test stair selected was one that represented a typical high rise building stair such as those found in 2008-2010 Case Study Buildings, Numbers M1 and M3. The Adams and Galea Study (2010) comprised a multi storey ascent so that this will be allowed for in the discussion in the subsequent sections.

The stair geometry is where the pitch is approximately 38^0. This pitch resembles a steep stair so that the test addresses many of buildings constructed in accordance with the minimum going dimensions (250mm) and maximum riser dimensions (195mm). It is therefore considered to be a conservative pitch in terms of the performance of the Evac-chair® vehicle, especially the model 1-440[130].

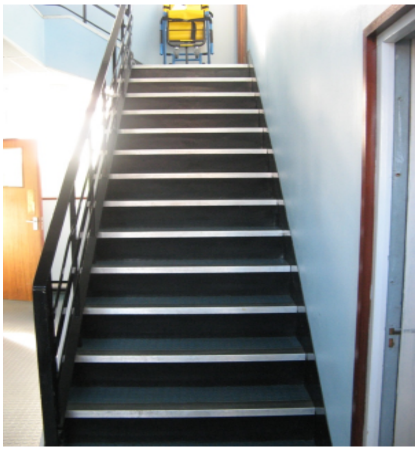


Figure 4-25: View looking up the test flight

[130] Model with passenger capacity of 200Kg.

Figure 4-25 shows a typical front view of the test stair flight. The nosing contrasted with the dark vinyl floor covering and the black handrails with the light coloured walls. There were a total of thirteen risers.

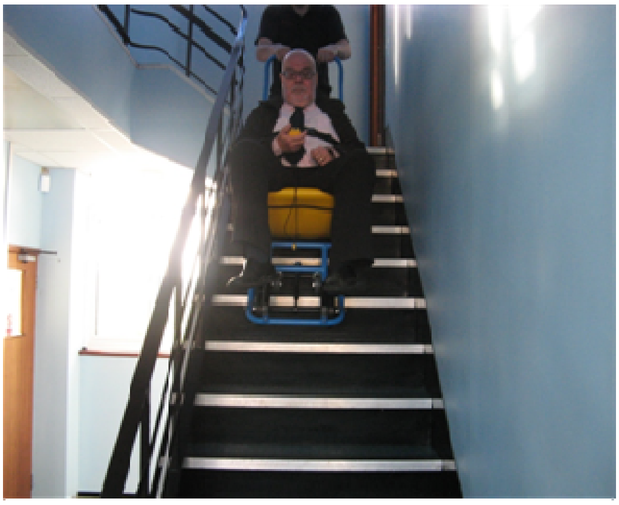


Figure 4-26: Test run no. 4 with a single operator

Figure 4-27: Test 6 with 2 operators

Figure 4-26 and Figure 4-27 show the author during tests 4 and 6. Note that the author is below the limit recommended for a single operator but in such instances the operator would be expected to have been properly trained and to participate in this capacity during each trial evacuation.

Adams and Galea (2010) utilised a 75kg subject for the Evac-chair test. The likely BMI would have been 22. The author being the person immersed in the PhD case study is still classified as Class III obese having a BMI of 33. During the 1980's he had a BMI of 56. In order to view the descent speed results from the Adams and Galea (2010) study in context the author conducted a test with the permission of the suppliers of Evac-chair using the model 1-440 as the descent vehicle. This model is designed to carry people with a mass limit of 200Kg or 440 lbs.

A total of six test runs were conducted for the reason of internal validity so that the comparison with the Adams and Galea (2010) study could be placed in context. The results are presented in Chapter 7.

4.4 The 2008-2010 Case Study – Building Particulars

The 2008 – 2010 Case Study was undertaken in three Plan-Do-Study-Act Cycles as explained in Chapter 4. Each of the buildings has been coded as follows:

- PDSA Cycle 1 – Building M1 – Christchurch – 10 storeys and Building M2 – UAE – 36 storeys.
- PDSA Cycle 2 – Building M4 – Wellington 1 -26 storeys and Building M3 – Manchester (UK) – 17 storeys.
- PDSA Cycle 3 – Building M5 – Wellington 2 – 18 storeys and Building M6 – 34 storeys.

The descriptions included in this section comprise floor plans and annotated sketches of the main fire stairs. No internal photographs are included for some due to the requirements of the Owners/ Facility Managers. Each building also includes some information on the trial evacuation set up and procedures.

Each section also includes a summary of the trial evacuation exercise. The video camcorders that were used are shown in Figure 4-28 and the mounting is described in Chapter 3. These cameras were able to operate in low levels of illumination and were extremely easy to operate especially in terms of ensuring that each “view” told the story for that level. The cameras were also equipped with full sound recording systems for additional observations. The Dictaphone Figure 4-29 was in the form of a cassette recorder which was supplied with a lapel microphone so that the observer could be less obtrusive if this was required.

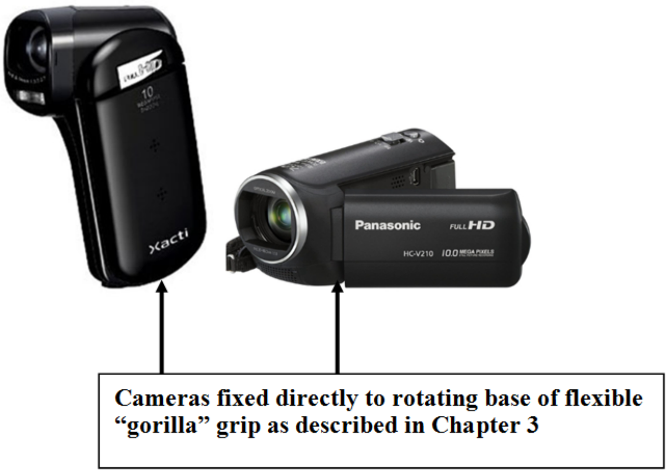


Figure 4-28: Main video camcorders used to record occupant progress when going down the stairs.

View from above

Side View of Controls

Figure 4-29: Views of typical "Dictaphone" (cassette recorder) used by observers.

4.4.1 Building M1: PDSA Cycle 1 – Christchurch, NZ, 10 storeys.

Building Particulars

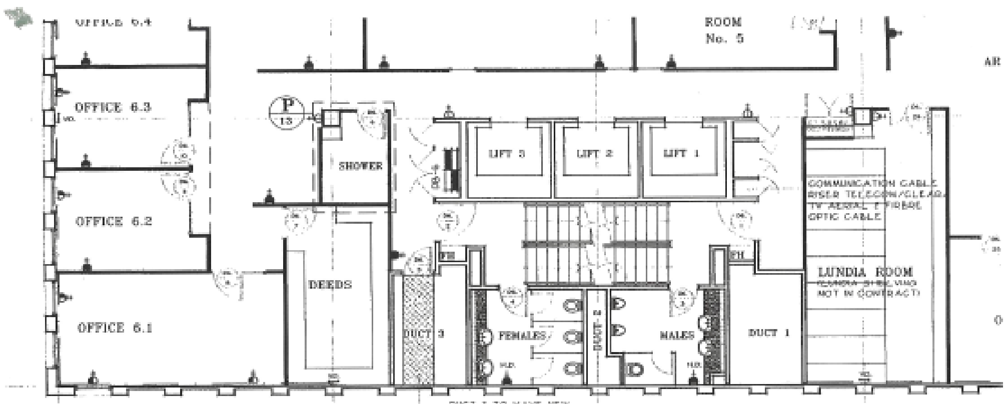


Figure 4-30: Lobby and stair plan on typical floor - Building M1

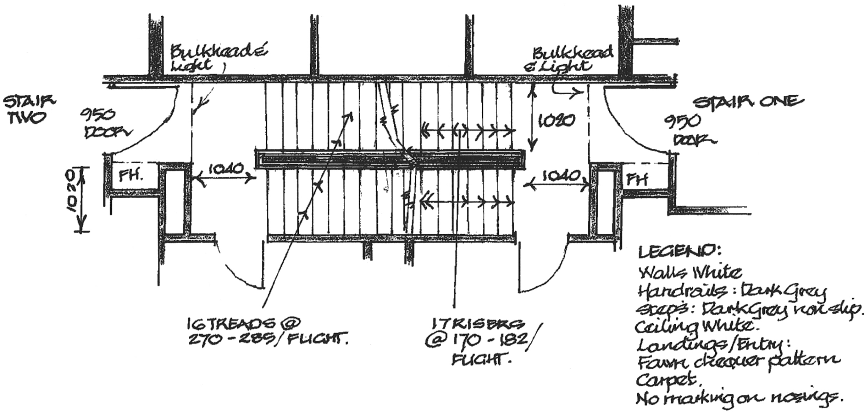


Figure 4-31: Dimensioned plan view of scissor stairs - Building M1

The Christchurch Office Building (M1) comprises a 10 storey office building with a ground floor of retail shops and 9 floors of office space with a gross area of some 300m^2 per floor (see Figure 4-30). The building is provided with two fire stairs in the form of fire separated scissor stairs. There is no void or well between the flights and there is only one 'turn' per floor. Unfortunately both of the stairs discharge into a common corridor at ground level and there is a reduction in width or exit carrying capacity. The walls are a light colour with the stairs being covered with a grey colour vinyl sheet. Aluminium nosing strips are used to delineate the stairs. There is a single pipe handrail (dark grey) on the inside wall as described in Figure 4-31. On the day of the evacuation trial only the fire wardens had been notified of the drill but it is highly likely that news about the drill leaked out to the other occupants. Trial evacuations are held once per annum and are under the direction of evacuation safety specialists in the employ of the Facility Manager.

The stairs should be familiar to the occupants as the male and female toilets are located within the fire stair 'envelope' or enclosure.

The assessment of the stair environment may be found in Appendix A4. An extremely dark visual image of one of the typical flights in stair one is shown in Figure 4-32 below:

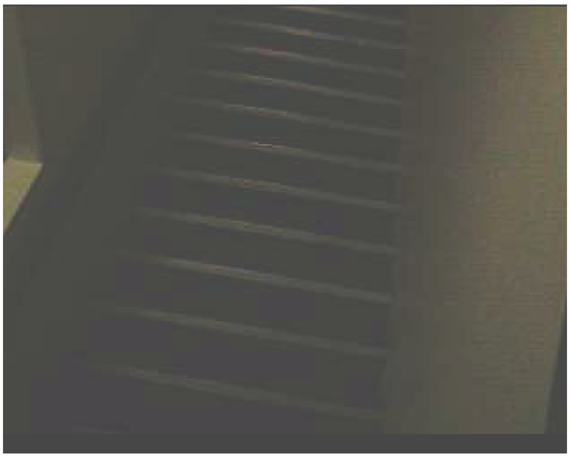


Figure 4-32: **Visual Image (Dark) of typical stair flight in Stair 1.**

Summary of trial evacuation for M1.

On the night before the evacuation the video camcorders were positioned in the stairs on all levels with one per stair (scissor stair) which meant that in each of the stair systems there was one camera every two levels. There were an additional two camcorders covering the final exits on the ground floor. The team comprising eight fire engineers were fully briefed 30 minutes before the exercise. They were supplied with fully charged and tested Dictaphones. Five minutes before the evacuation signal was due to be activated the observers proceeded to their assigned floors[131] which were two on level 10, two on level 7 and two on level 3 with the remaining two at the final exits on the ground floor. At the same time the ground floor observers proceeded down the stairs from the top storey and switched on the camcorders as they went. The evacuation signal was sounded by the evacuation consultant and all the occupants evacuated at once (uncontrolled evacuation strategy – “one out all out”. All the occupants left in an orderly fashion and the building was evacuated in some five minutes. There

[131] Five minutes before the evacuation signal.

were delays as expected in the ground floor corridor. All the questionnaires were handed out by the two observers on the ground floor and were collected from the fire wardens on each floor as arranged at the briefing meeting held the week before the exercise was held. The follow up questionnaire was handed out when the others were collected. The follow up questionnaires were picked up two days later but the response rate was below ten percent. The video camcorders were also removed and the digital memory cards were extracted and marked as to their level and stair number. The same procedure was followed for the cassette tapes. All the raw data was then transferred into electronic folders marked "M1-Trial Evacuation, ready for analysis.

4.4.2 Building M2: PDSA Cycle 1 - 36 storeys in UAE.

Building Particulars

This building, located in a typical UAE Business Park, comprises two levels of car parking and 34 floors of 'freehold' office space' with typical subdivisions on each floor as shown in Figure 4-33. Each office is supplied with their own amenities. The net floor area per level is approximately 600m^2 with an extremely low occupant density of approximately 0.05 persons/m^2. This establishes an occupancy level of approximately 30 per floor.

The building is provided with two separate fire stairs where the treads are 300mm and the risers 150mm, with extremely comfortable step geometry. Two handrails are provided which are circular, but oversize, being 60mm in diameter. They are not continuous at each level. The stair has a conventional dog leg configuration. Ventilation is provided to the stairs in the form of a pressurisation system and the shafts are provided with emergency lighting. A clear width of 1020mm plus is provided. (See Figure 4-34 for additional plans and a typical section through the stairs).

The floor covering is a cream coloured ceramic tile profiled on the nosings. No contrast is provided between the steps, landings and wall seeing the walls are white. The handrails are also white so that none of the safety elements are legible in any way. Orientation is compromised by the lack of signage on each level. Comments about lack of contrast and continuity of handrails can be seen in Figure 4-35

Summary of trial evacuation for M2

The fire/ evacuation alarms were set for a sequential evacuation. They were activated for four floors at a time at three minute intervals. The lifts were designed to return to the ground floor and be locked off. As the alarms sounded, the emergency team provided the occupants with instructions. Each 'office owner' was required to provide their own warden and was expected to evacuate in an office group. Cameras were provided on every third floor. Only six observers were used due the difficulty of raising the necessary resources on the day although a total of twelve observers had been ear marked for the trial. This resulted in two observers on Levels 34, 21 and 13. The questionnaires were handed out by the facility manager's staff to the occupants as they arrived at the assembly point. The observers were briefed as per M1 but their assigned floors had to be changed at the last minute because the rest of the team had been called away on business at the last minute.

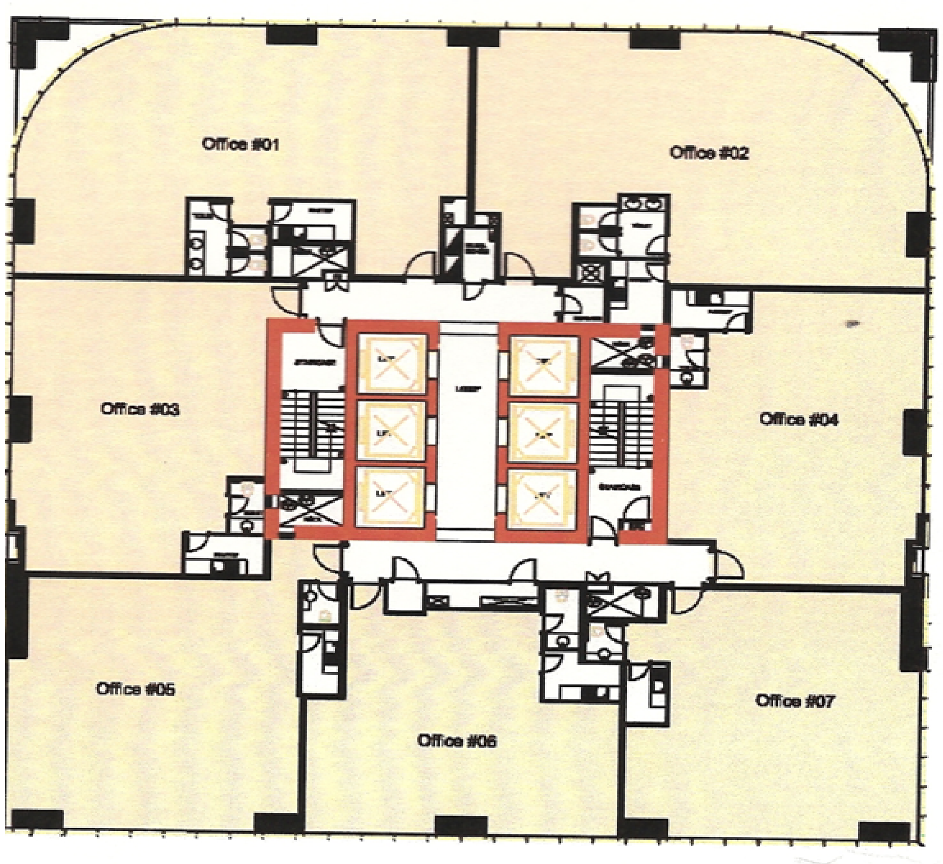
This case study could have been dispensed with due to the fact that the building systems failed and the evacuation was not completed. No timed stair descent data was gathered as:

- Lifts did not return to the ground floor so that many of the occupants used the lifts instead of the stairs.
- Levels 33 refused to evacuate (Observer report)
- Level 23 did evacuate but only with a total of 10 people, 2 using the South Stair and 8 the North Stair. The 8 people took 12.5 minutes to descend through 21 floors and the others took 15 minutes.
- The alarms did not sound on many of the levels so that occupants on those floors were confused and did not respond.

- The temperature inside the stairs was 40^0C + and the stair pressurisation fans failed so that air was not moving through the shafts.
- Approximately 150 persons completed the evacuation and the Author was required to debrief them.
- Two falling incidents occurred which will be fully analysed in Chapter 7.
- Level 13 did not evacuate and the two observers on this level were required to report to the debriefing area some 20 minutes after the first set of alarms had sounded.
- Because of the excessive temperatures in the stairs some of the cameras had been dislodged and damaged due to the industrial “tape” used to hold them in position had delaminated from the walls.

The questionnaires were collected the following day by the facility manager’s staff and coded in accordance with the author’s instructions. The follow-up questionnaires were handed out on the same day by the facility manager’s staff and collected the following day. Once again the response rate on the follow-up questionnaire was less than ten percent.

There were two “falling” incidents reported, one in each stair. The first fall involved a mature age male who haemorrhaged during descent and needed attention from paramedics as well as being taken to hospital. It was attributed to heat stress according to the observer. The other falling incident was that of a morbidly obese male hurrying down the stairs. He commented that he was tired and found it difficult to focus especially with the illegibility of the steps (Figure 4-35). The male missed his footing at a mid-landing level stepping off the second last step and fell coming to rest on the ground. He was assisted out of the building and placed in a wheelchair. These two falls are analysed and discussed further in Chapter 7.



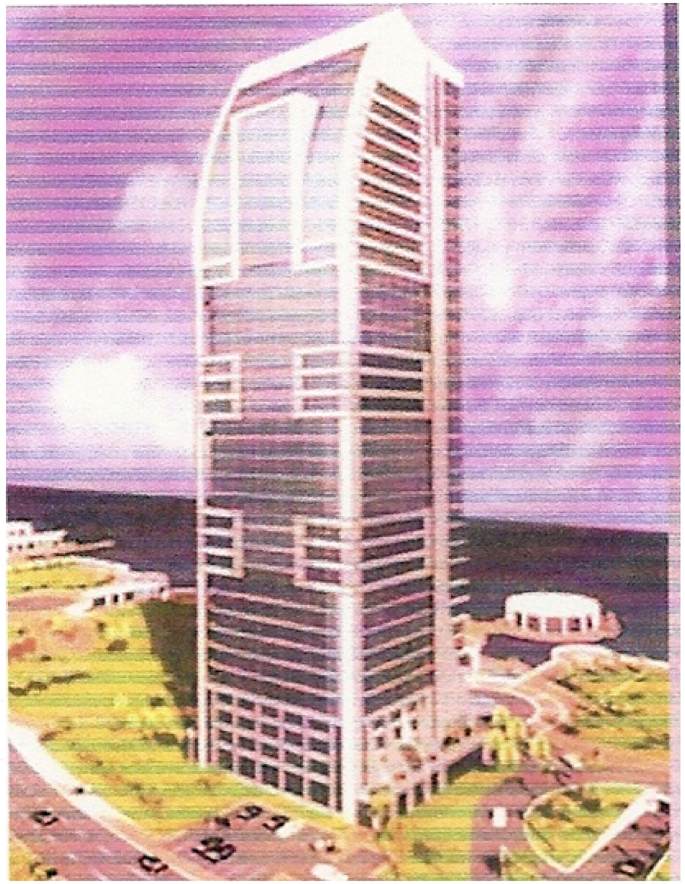


Figure 4-33: **Typical Floor Plan and Perspective**

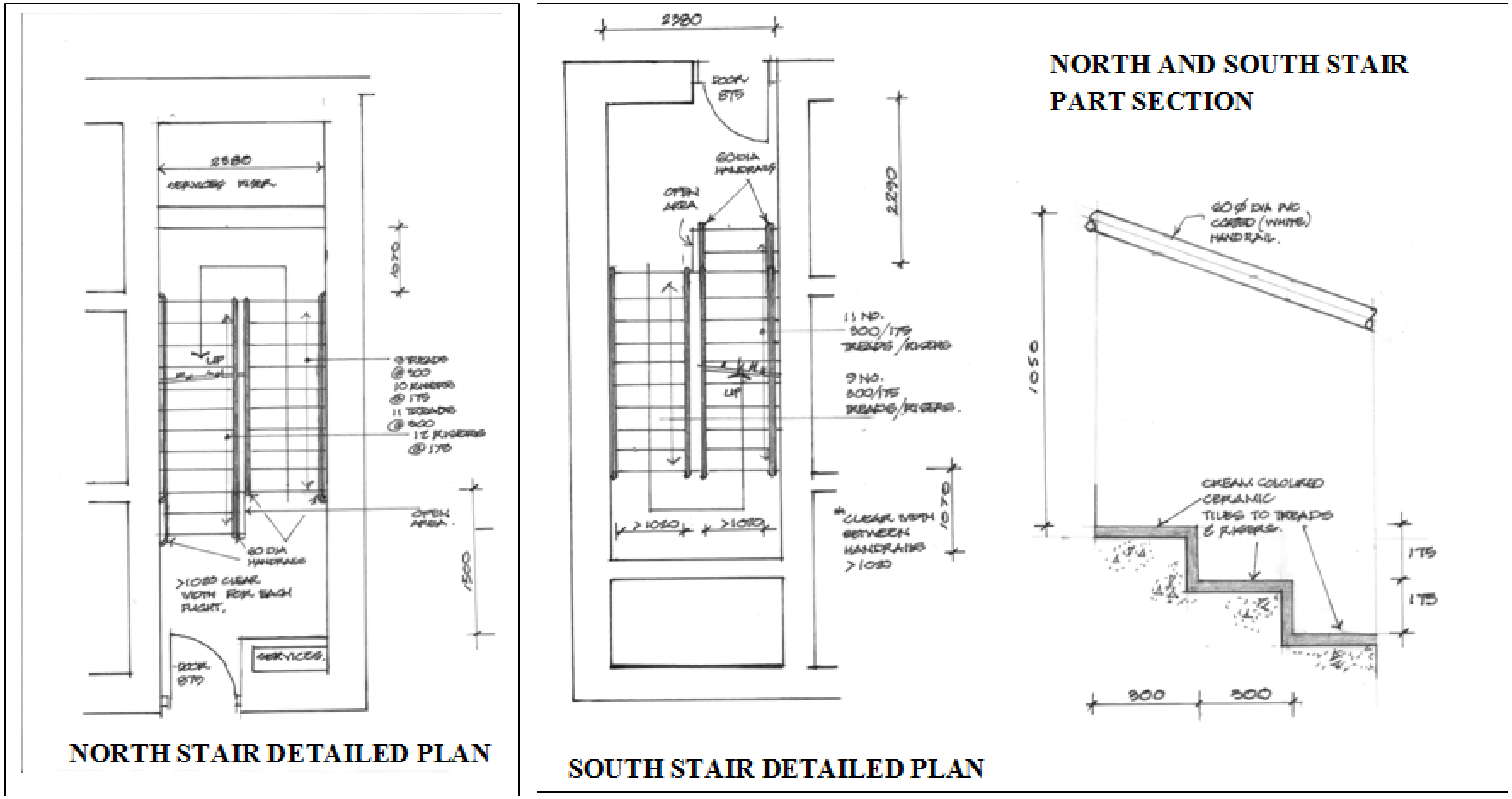


Figure 4-34: Stair Details Building M2 UAE

Internal Views of Building M2 Stairs

- *Showing lack of contrast*
- *Resting space available*
- *Lack of signage*

1 – Looking down the flight from entry door; 2- Mid landing – entry door; 3- Handrail and side view of flight; 4- Room for resting and 5- Gap at landing between handrail panels – discontinuous.

Figure 4-35: Visual Images of Building M2 Stairs as noted

4.4.3 Building M4: PDSA Cycle 2 – 26 storeys – Wellington, NZ

Building Particulars

Building M4 is located in Wellington, New Zealand. It has a gross floor area of 1000m2 per level with an approximate occupancy rate of 0.05 persons /m^2. Levels 15 and 16 comprise plant rooms and are not occupied. The lowest three levels of the building are used for car parking (Figure 4-36)

The fire stairs are located in the central core of the building and comprise two sets of fire separated stairs. The configuration is very similar to Building M3. Due to the sloping nature of the site the stairs discharge to the outside of the building at Level 3. There is only one turn per storey in the stairs and each flight is provided with an intermediate landing. The clear width is approximately 1000mm and two handrails are provided with a diameter of 40mm diameter. The treads are 260mm wide and the risers 150mm high. A dark coloured vinyl floor covering is used on the stairs. The stair environment assessment may be viewed in Appendix A4. Occupants of Levels 25 and 26 are always pre-warned when trial evacuations are to be held due to the nature of their operations. Data from these two levels have therefore been deleted from this study. There is a small annex included with this building but this annex was also ignored seeing it was equipped with its own stair for reasons of simplicity and availability of coding resources.

The floors are occupied by various organisations many of which are spread over more than one floor. The stairs were used for inter floor communication so that some of the occupants would have been reasonably familiar with these stairs.

Summary of trial evacuation for M4

Following a review of the trial evacuations in M1 and M2 it was decided to dispense with the follow up questionnaire and absorb the questions on fitness into the main instrument. The mountings of the video camcorders were also reviewed and a new bracket trialled and found to be extremely flexible in that it could be fixed to handrails or hydrant risers affording a better "view" of the descending occupants. This bracket is fully described in Chapter 3.

On the day before the trial evacuation the camcorders were fixed in position being every third level and one above each final exit. Observers met for their briefing some twenty minutes prior to the commencement of the evacuation. The team was made up of fire engineers from the author's previous practice in Wellington. Observers were located approximately every four levels. There were 300 occupants from 21 levels using Stair 1. This results in an average of 14 occupants per level.

The lifts returned to the ground floor on fire alarm and the evacuation sequence was that of an uncontrolled evacuation (all out at once). The total evacuation time was of the order of 10 minutes which indicates a reasonably rapid descent rate. Trials are held once per annum as part of the legal requirements of the New Zealand Fire Safety and Evacuation of Buildings Regulations. The stair environment assessment coding sheet may be viewed in Appendix A4 and the results are presented in Chapter 7.

The questionnaires were handed out on completion of the exercise to the floor wardens who then supplied them to the occupants. The questionnaires were collected on some two days later. The equipment was removed on completion of the evacuation and the data transferred into an electronic folder as per M1 ready for analysis.

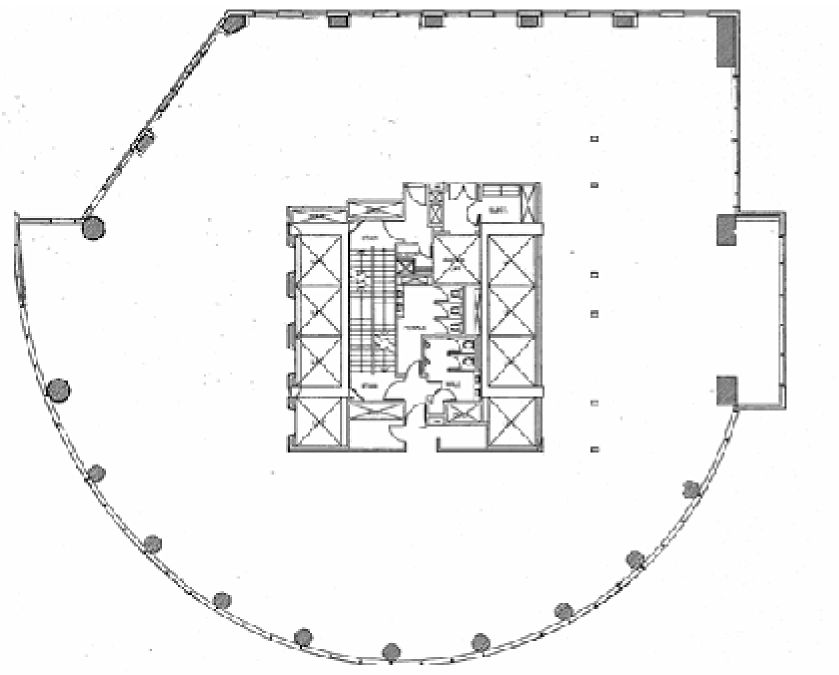


Figure 4-36: CYCLE TWO, BUILDING M4 – WELLINGTON 1 – 26 STOREY OFFICE BUILDING – TYPICAL FLOOR PLAN AND ELEVATION

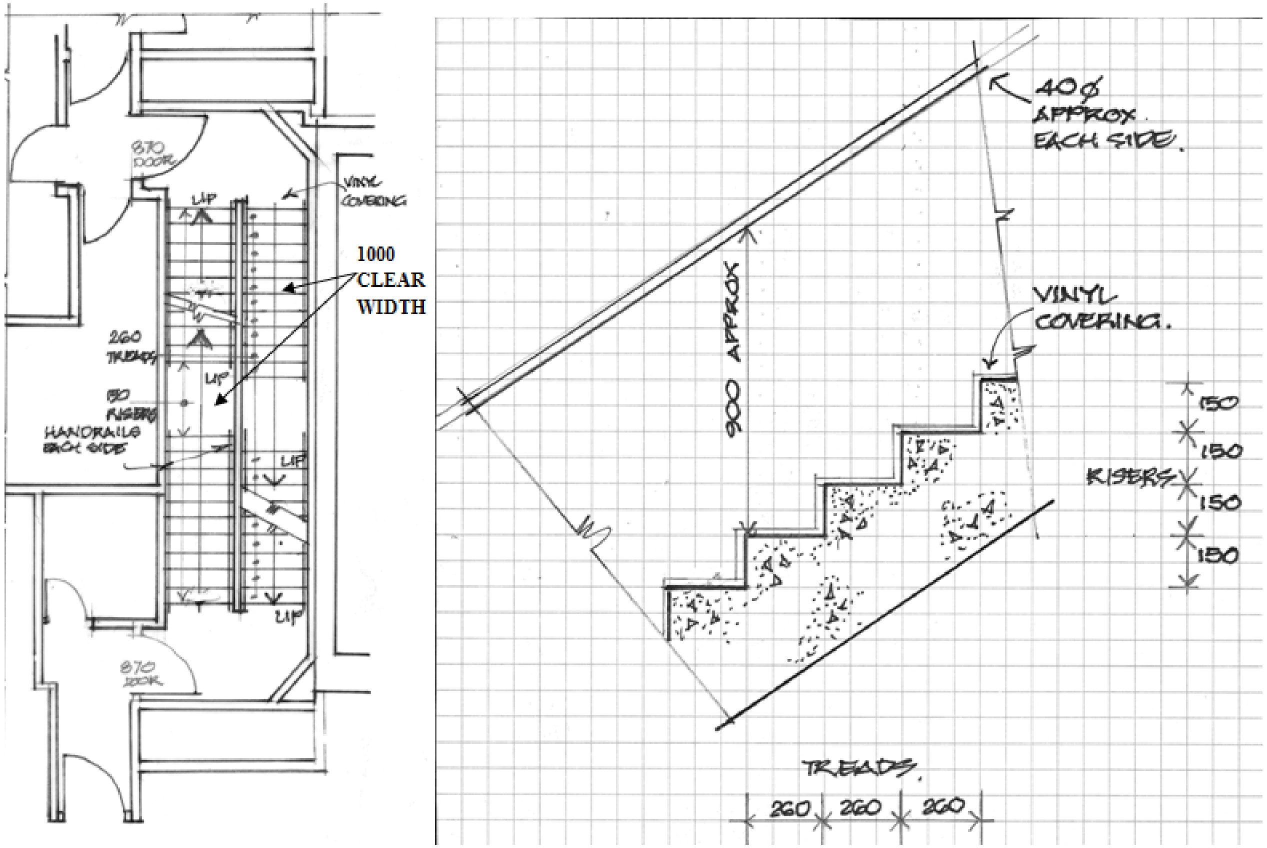


Figure 4-37: Diagrammatic Plan of Scissor Stairs and Part Section

4.4.4 Building M3: PDSA Cycle 2 – 19 storeys – Manchester UK.

Building Particulars

Building M3 is a 17 storey Office Building located in Manchester, United Kingdom. The Ground Floor comprises some retail and there are two levels of serviced offices. The floor area is some 300m2 per floor and the occupancy rate varies. An average rate would be $9.5m^2$ per person. Plans, sections and other visual images may be found in figures 4-38 to 4-42.

There are two stairs in the building. The main stair (referred to as the Clean Stair) is the main stair located adjacent to the lifts. This stair is carpeted and nosing sections provided to each step. The walls are a white colour and the carpet a dark brown. Some support is provided by a single handrail which is dark and comprises 35mm square steel sections broken by the support posts so graspability could be a problem. The treads are only 245mm wide with 190mm high risers. As such the stair is found by many of the occupants to be steep. A clear width of between 940 and 960mm is provided which is sufficient for a single or staggered arrangement of occupants when descending the stairs. The stairs are not extremely well defined.

The other stair is located in a shaft external to the building. At one time this stair was an open stair but is now fully enclosed. This stair comprises exposed concrete treads with yellow markings to the nosings. Lack of maintenance is the problem. The shaft was cleaned out for the purposes of the trial evacuation. Once it had been cleaned out and the few obstructions removed then it proved to be quite serviceable.

The handrail comprises a 35mm square section as per the Main Stair but the graspability is better because the support posts are not so intrusive. Although there is no contrast between the concrete walls and stair flights, the nosings are clearly marked in a yellow colour and handrails are red. The treads are 250mm wide and the risers 190mm which is exactly the same geometry as Building M6. The clear width varies between 970mm and 980mm.

Summary of trial evacuation of M3

The trial evacuation sequence is an uncontrolled one i.e. everyone evacuates at the same time. Stair usage is somewhat uneven but seeing the Main Stairs are the ones normally used the split is somewhat expected. The Dirty Stair was used by 60% of the occupants of Levels 7 and 8, 100% of the occupants from Level 11, 30% of the occupants from Levels 12 and 13, 50% of the occupants from Level 16 and 40% from Level 17. The overall split between the stairs was 35% for the Dirty Stair and 65% for the Main or Clean Stair.

Some children took part in the evacuation entering from Level 9.This was further complicated by some parents carrying strollers along with toddlers in their arms thereby causing some "platooning" in the stairs behind them. The wardens, however, were vigilant and the evacuation was still orderly and the parents and children were not placed at risk. The overall evacuation time was some 7 minutes.

Cameras were located on every third level and only three observers were used, once again because of the availability of resources on the day. One observer descended the dirty stair from level 17 and the other two observers in the Main Stair from Levels 17 and Level 10. Entry from Level 10 was extremely useful because of the problems associated with Level 9. The results are presented in Chapter 7.

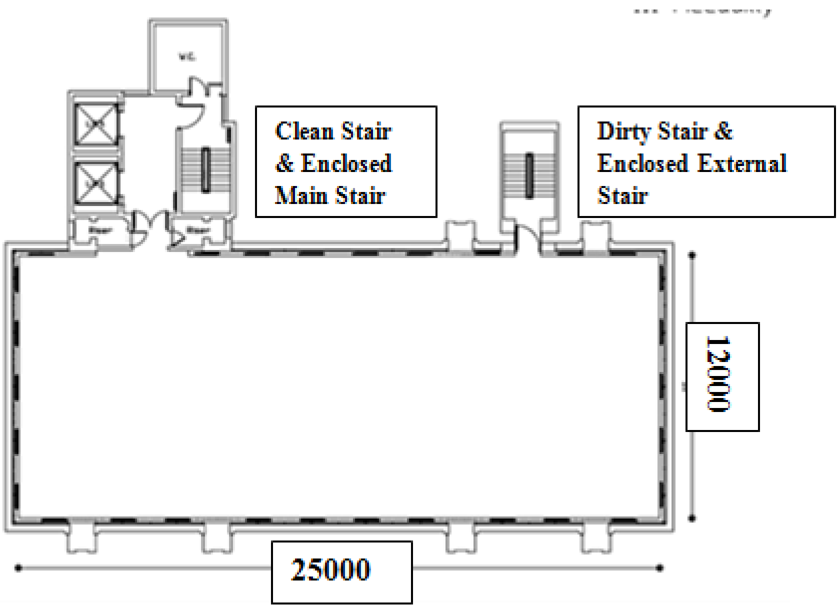


Figure 4-38: **Typical Floor Plan for Building M3**

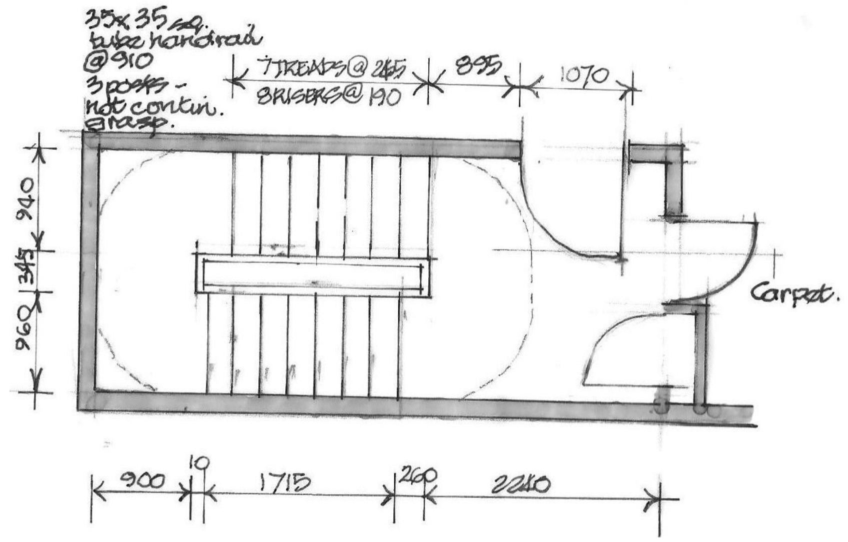


Figure 4-39: **Clean or Main Stair Building M3 – Plan View**

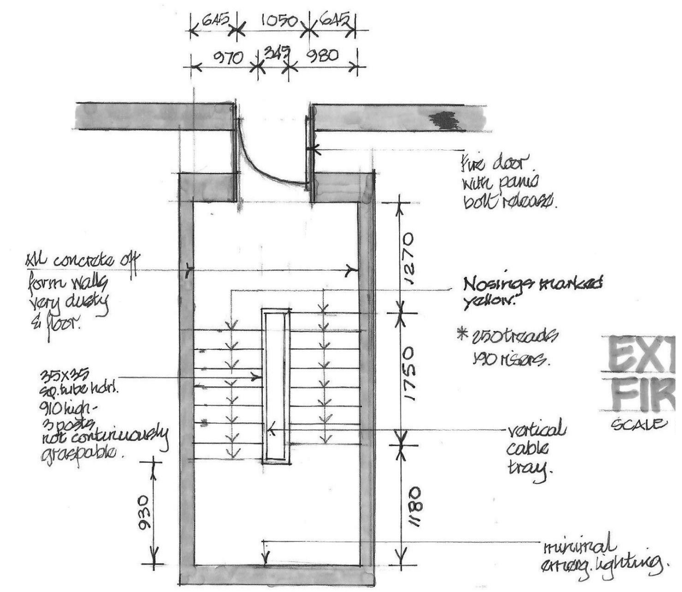


Figure 4-40: **Dirty or External Stair – Building M3 – Plan View**

Questionnaires were handed out at the assembly points on completion of the evacuation and collected the day after. The equipment was removed immediately on completion of the evacuation and the data transferred into an electronic folder as per M1 ready for analysis. An important point to note is that this was the first building that the new brackets were tested on. The bulk of them were attached to handrails and pipes as per M4. This method of fixing was therefore maintained for the remaining trial evacuations.

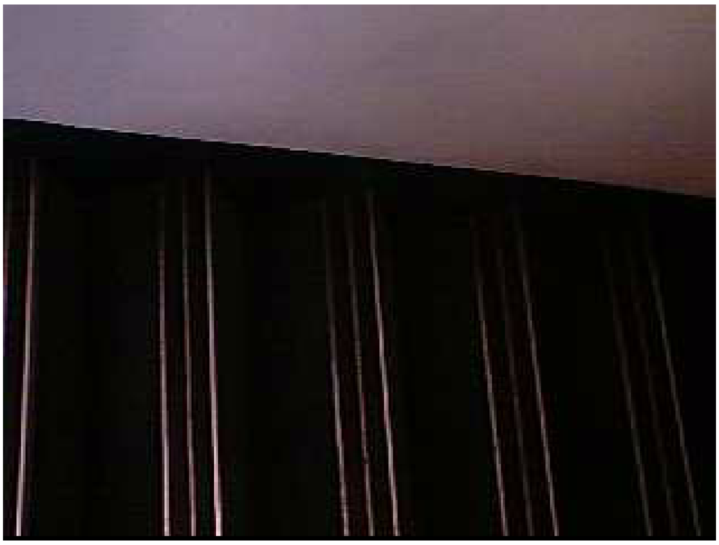


Figure 4-41: Plan View of Main Stair Flight Building M3

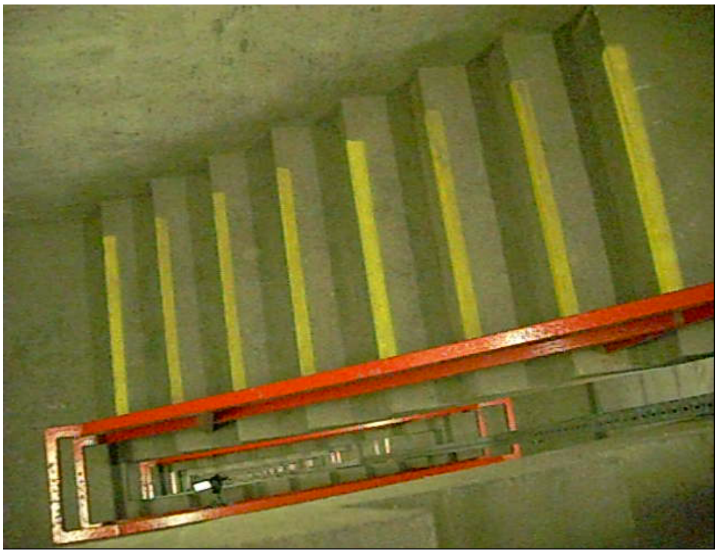


Figure 4-42: Overhead View of Dirty Stair Flight – Building M3

4.4.5 Building M5: PDSA Cycle 3 – IPAQ

Building Particulars

Building M5 is located in Wellington, New Zealand and comprises 17 levels of 1300m2 per level. The aspect ratio of the typical floor is 4.5:1. Stairs 1 and 2 are located some distances from one another and they discharge at Level 3 due to a sloping site. For plans and other visual images of the building see Figure 4-43 to Figure 4-45(B)

The treads are 270mm wide and the risers were open having a height of 175mm. An open void exists around a winding stair with two intermediate landings between each level. This involves 4 turns and stairs that experience some vibration under crowd conditions. The clear width between the single handrail and the wall is 1045mm on the main flights. The handrail comprises a rectangular timber section which is extremely difficult to grasp. Further details are available on the environment coding sheet for Building M5 in Appendix A4

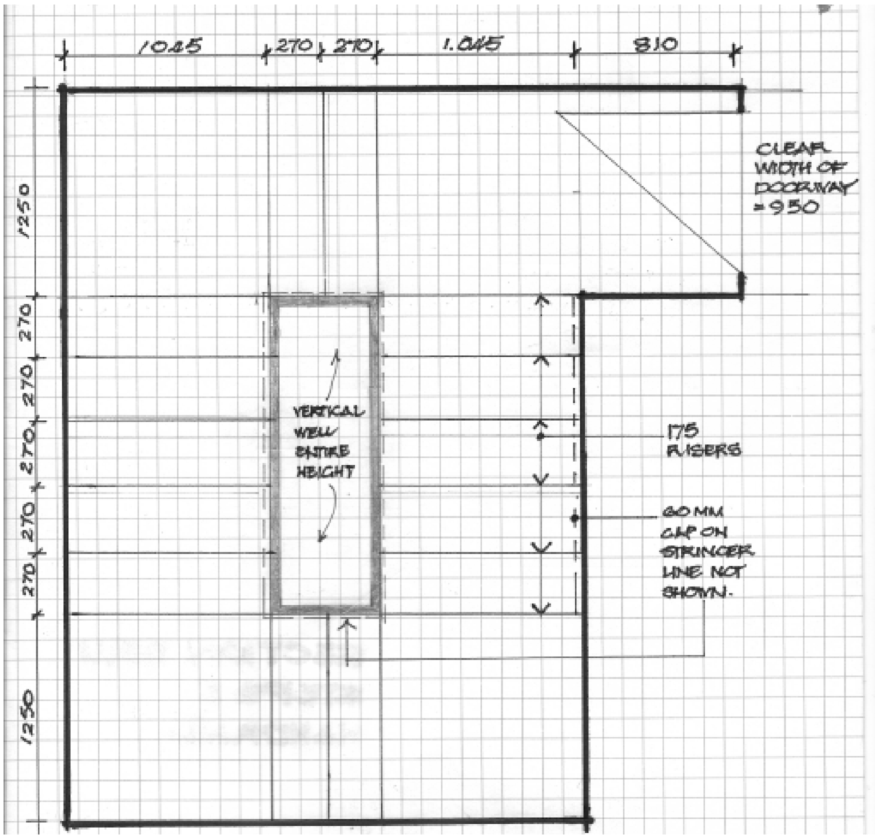
Stair 1 served 255 occupants for 13 levels which is an average of 19 occupants per storey. This would not appear to result in a high density but most likely due to extensive delays due to uneven loading from some of the levels. This will depend on the detailed results presented in Chapter 7.

Summary of trial evacuation of M5

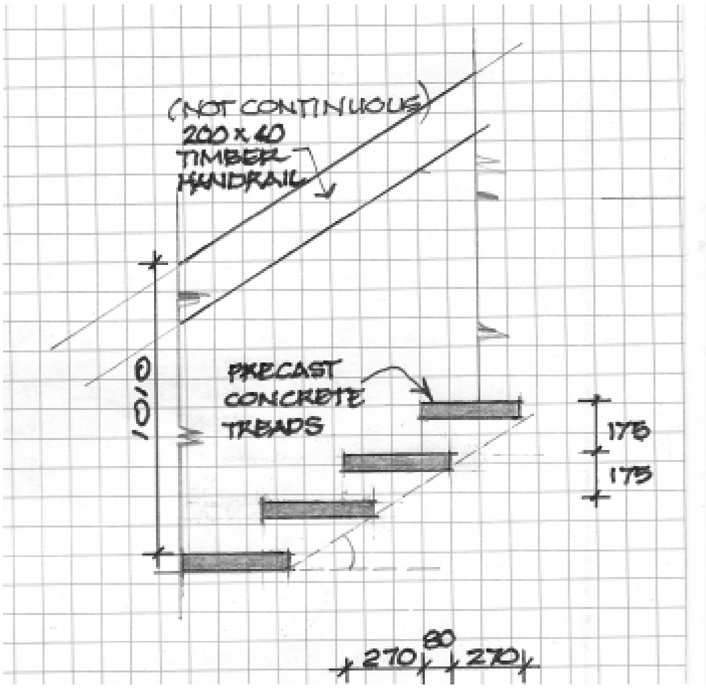
The evacuation strategy for the building is satisfied by an uncontrolled evacuation where everyone supposedly enters the stairs at the same time. The overall evacuation time was approximately 9 minutes.

Figure 4-43: Building M5 Typical Floor Plan

Figure 4-44: Building M5 Elevation and Perspective



PART DETAILED PLAN OF STAIR ONE AND STAIR TWO (A)



PART DETAILED SECTION STAIRS ONE AND TWO (B)
Figure 4-45 (A) and (B): **Stairs One and Two Details Building M5**

There were a total of six observers for the stairs so that two were positioned on the top floor (one per stair), two on level nine and two on level four. The observers met in the lobby on the day before and the briefing was short because it was the same team that was involved on M4. They proceeded to their assigned levels and stairs ten minutes before the evacuation alarm. The observers for level 4 were responsible for switching on the video cameras. Camcorders were placed on every second floor with one above each final exit.

The rate of descent appears to have been slow and steady due to the rapid occupant response from each floor. Queues formed and there were delays. Because the drill was held regularly twice per annum, the occupants were familiar with conditions entering and within t6he stairs. Building M5 was expected to contradict the results of fatigue from the other buildings because of the large number of people in the stair at the one time and the fact that this slowed everyone down. No one appeared to "hurry" down the stairs so that there was every chance that the theory of increased density masking fatigue (Galea et al, 2011) could be explained.

The equipment was removed on completion of the trial evacuation and the data transferred into an electronic folder ready for analysis. See Chapter 7 for the results.

4.4.6 Building M6: PDSA Cycle 3 – IPAQ – 34 storeys, Sydney, Australia.

Building Particulars and Designated Stair System (Sequential Evacuation)

Building M6 comprises a 34 storey office building with a total of three fire stairs. These stairs all discharge to the outside via a series of long fire isolated corridors requiring occupants to firstly descend into a basement area in some cases and then to climb again to street level where the system finally discharges.

The typical floor plans for all levels up to level 19 are shown in Figure 4 46 to Figure 4-47 and the upper levels in Figure 4-48 to Figure 4-49 There are three stairs each of which are designated stairs for evacuations along with the sequence of entry. The designations are:

- Stair 1 - Levels 5, 8, 11, 14, 17, 20, 22, 24, 26, 28, 30 and 32.
- Stair 2 – Levels 6, 9, 12, 15, 18, 21, 23, 25, 27, 29, and 31
- Stair 3 – Levels 7, 10, 13, 16 and 19.

The alarm sequences are:

- First phase: Levels 5-7
- Second phase: Levels 8-10
- Third phase: Levels 11-13
- Fourth phase: Levels 14-16
- Fifth phase: Levels 17-19
- Sixth phase: Levels 20, 21, 31 and 32
- Seventh phase: Levels 22, 23, 29 and 30.
- Eighth phase: Levels 24-27

- Final phase: Levels 28.
- Stair entry intervals of approximately 10 minutes depending on clearance times from other floors.

The stairs have two intermediate landings with four turns per storey. The number of steps per flight varies and details of the various configurations can be seen in Figure 4-50 to Figure 4-52. The treads are 260mm wide and the risers 190mm. Each step is delineated by a yellow line set back slightly from the nosing. Otherwise there is little contrast and some occupants are concerned about this in that they lose sight of the steps when descending the stairs rapidly in a group (Figure 4-52). The handrails are also grey. Illumination within each stair generally exceeds 50 lux and emergency lighting is provided.

The clear width of the stairs exceeds 1000mm and, although stair two is the only one that appears to have a space for resting (recessed entry door), people were observed resting in stairs one and three without holding up the other occupants.

Summary of trial evacuation for M6

Building M6 is occupied at present by a single corporate tenant being a Banking Corporation. The tenant has an extremely strong commitment to workplace health and safety and holds regular trial evacuation drills with the full participation and co-operation of the NSW Fire Brigades. It should be noted that there is a recorded falling incidence for this building where the reported symptom was Vertigo. This incident was reported at the debriefing session and information was also gathered by the author from the intercommunication panel during the exercise.

The trial evacuation that was observed was held up initially via the activation of a smoke detector on Level 8 approximately 10 minutes before the commencement of the exercise. The evacuation strategy was satisfied via a phased or sequential evacuation sequence as described above and summarised in Table 4-1. This table should also be read in conjunction with the notes in Appendix A4 re the method used to co-ordinate and establish the real time time-line for the entire exercise.

This building was quite complex to set up for the gathering of data from observers and video cameras because of the height of the building and the number of stairs. Stairs 1 and 2, seeing they connected all 34 floors, were covered by camcorders at the rate of one every four floors. Stair three only connected 19 levels so that this stair was covered by five digital cameras operating on the video function. Data gathering from this stair was also supplemented via the use of additional observers. Observers in stairs 1 and 2 were located on every five floors starting on level 32 for Stair 2 and Level 31 for Stair 1. The full set up is summarised in Appendix A4.

The camcorder mountings were fixed in position the day before the evacuation as indicated using the new bracket system. The camcorders were fixed to the brackets some 30 minutes before the evacuation and switched on 5 minutes before the first alarm. The digital memory cards used with the camcorders had a capacity of some 90 minutes but in some instances this was insufficient. This did not prove to be a problem seeing the bulk of the problem was in stair three where the observer recorded data filled in the data gaps. The observers were fully briefed in the lobby before the evacuation and special attention was given to the potential problem with the camera capacity in stair three.

The author was located in the main incident control room with the chief warden and the communications officer. Table 4-1 was prepared from the recorded message analysis of the evacuation control panel. This was used as one of the main tools to reconstruct the stair descent chart together with CD's of the CCTV recordings of the flow in each one of the stairs at level 5.

It should also be noted that there was an additional incident where an occupant was unable to complete the exercise and was switched to the emergency lift where they were helped out by the Fire Brigade.

The equipment was removed from the building immediately after the drill and the data transferred to an electronic folder ready for analysis.

The results are presented in Chapter 7.

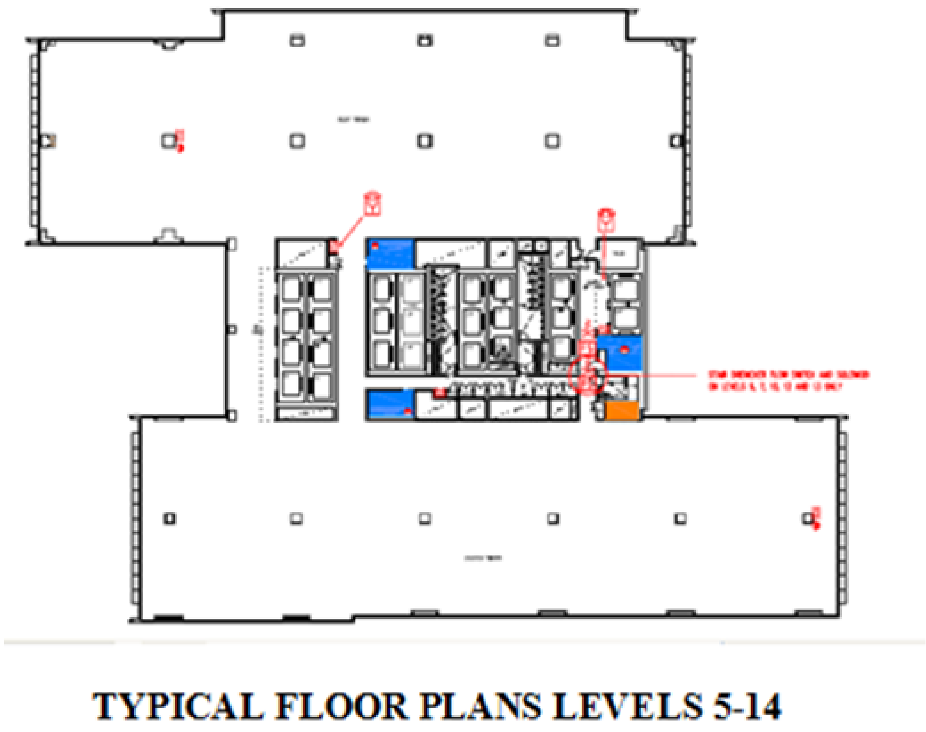


Figure 4 46: Typical floor plans for Low Rise Portion of M6

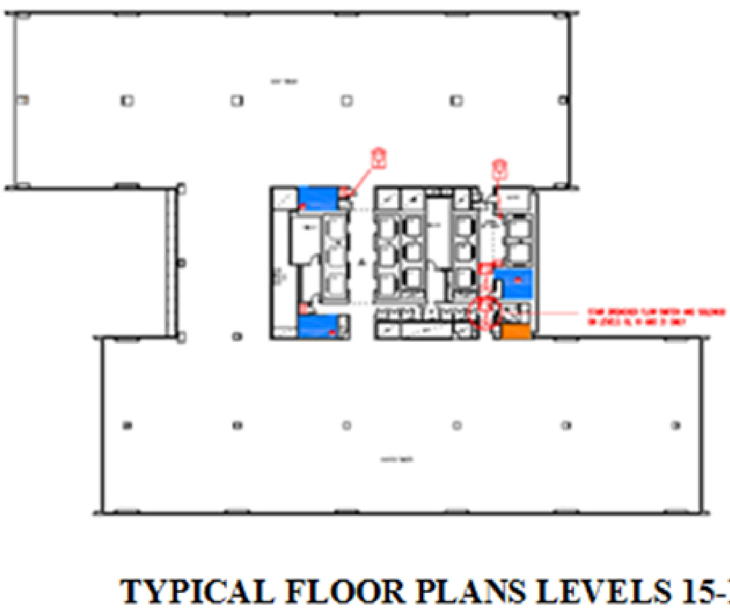


Figure 4-47: Midrise portion of Building M6

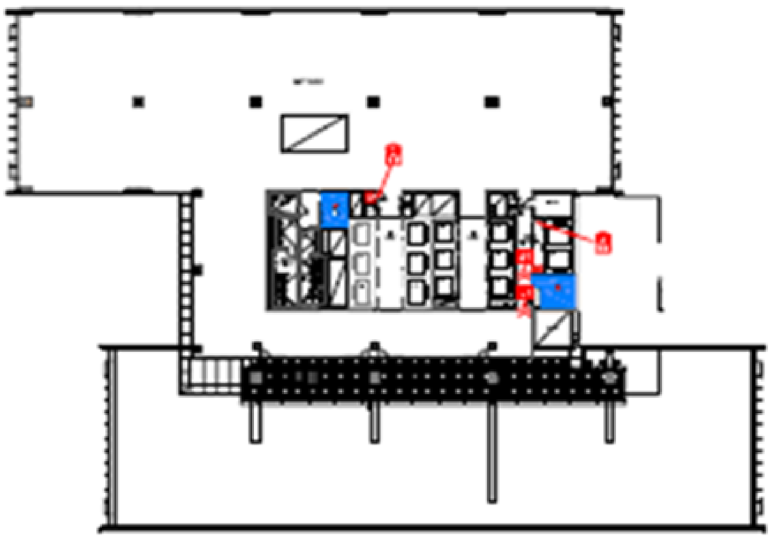


Figure 4-48: Change over mid to high rise Building M6

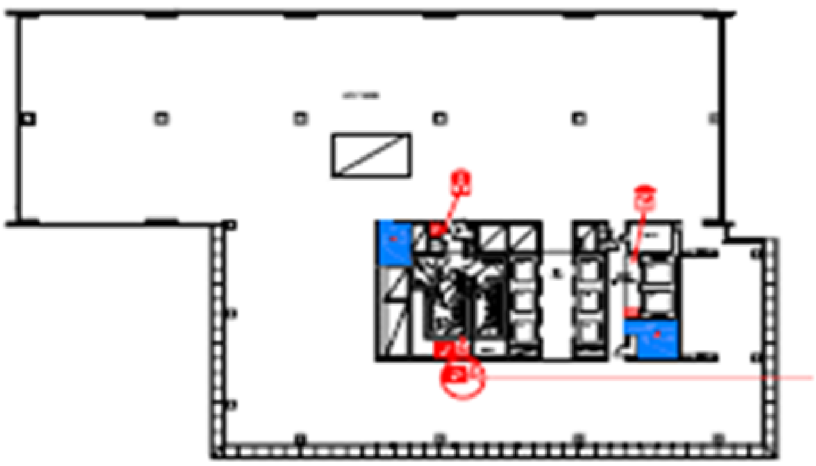


Figure 4-49: Typical floor plan of high rise portion of Building M6

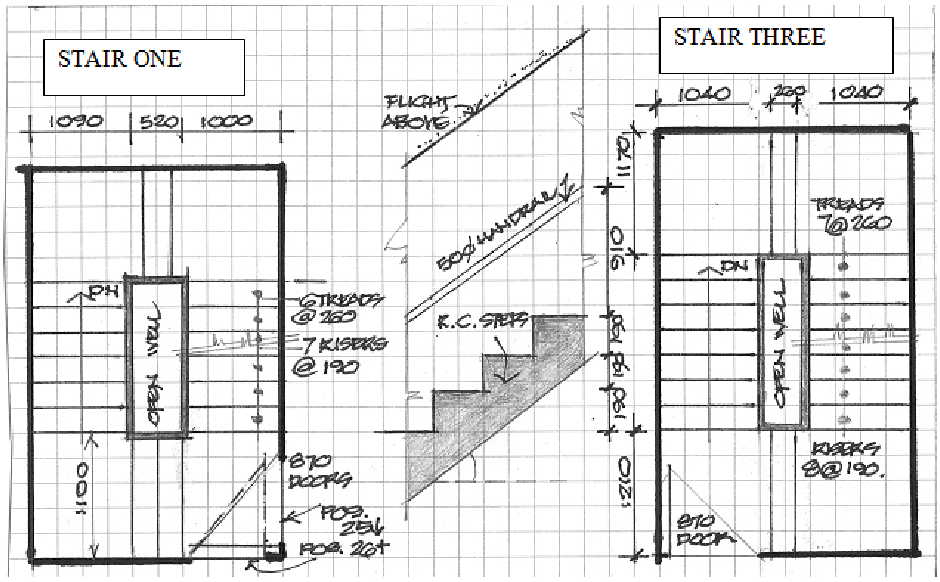


Figure 4-50: Detailed Plans Stairs 1 and 3 – Building M6 – See Part Section

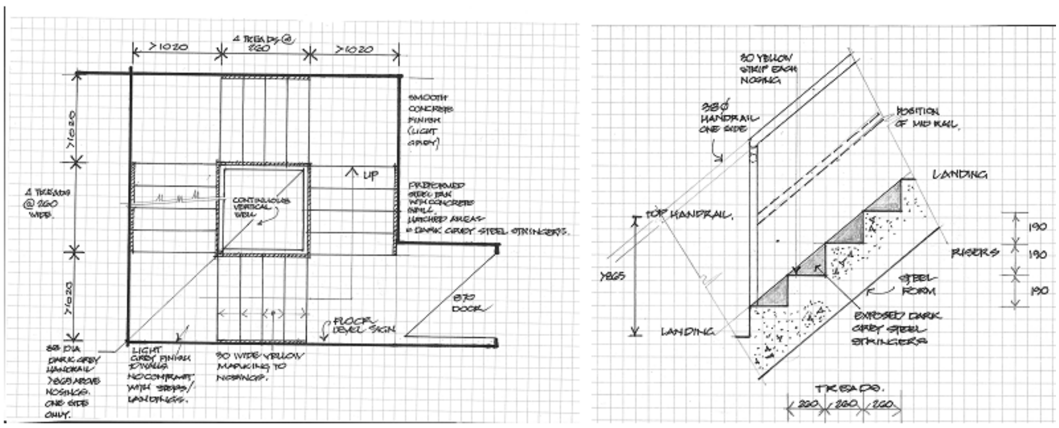


Figure 4-51: Stair 2 and Typical Section Stairs 1-3 for Building M6

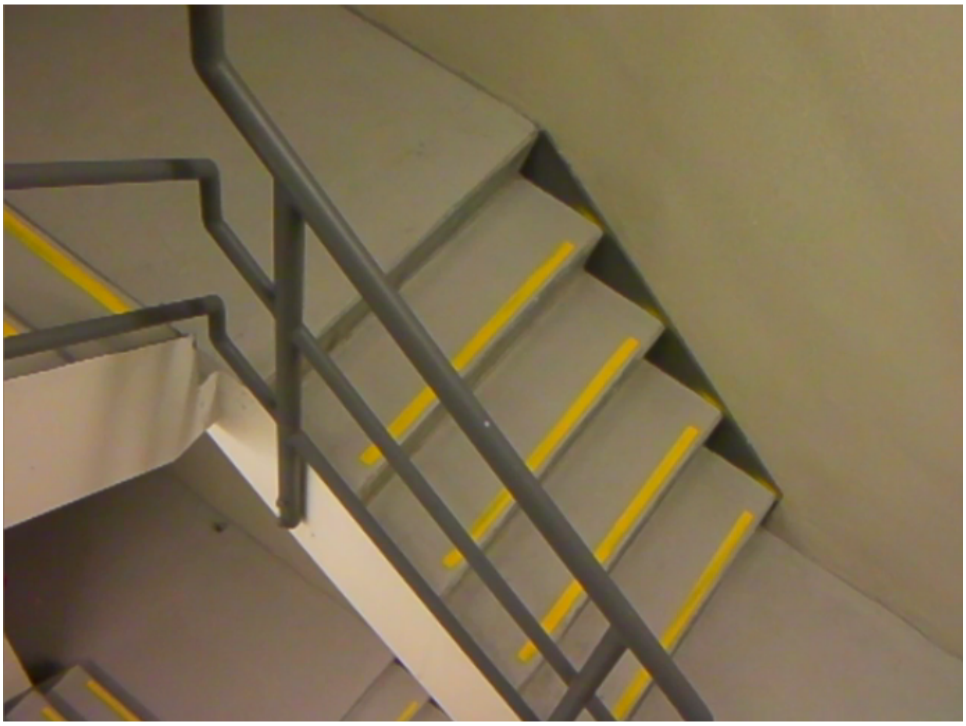


Figure 4-52-Internal View of Stair Two

Floor Number	Designated Stair No.	Mobility Impaired	Refusals	Alert Tone	Evacuation Tone	Flr Clear Warden	Floor cleared Fire Brigade	Comments
1		1	0	n/r	n/r	10.31	10.35	n/r = not required/ evacuated before upper levels
2		1	0	n/r	n/r	10.37	10.44	n/r = not required/evacuated before upper levels
3		0	0	n/r	n/r	10.38	10.38	n/r = not required/evacuated before upper levels
4		4	0	n/r	n/r	10.28	10.28	n/r = not required Level 4 was treated as fire floor
5	1	2	0	10.38	10.41	10.43	10.41	1 person found in central stairs on level 5 having wandered down from level 24 suffering from vertigo
6	2	1	0	10.38	10.41	10.46	10.51	
7	3	1	0	10.38	10.41	10.44	10.51	
8	1	6	0	10.46	10.49	10.52	10.57	
9	2	1	2	10.46	10.49	10.54	11.01	
10	3	7	0	10.46	10.49	10.57	11.03	
11	1	2	0	10.58	10.59	11.05	11.06	
12	2	6	4	10.58	10.59	11.10	11.15	
13	3	7	0	10.58	10.59	11.06	11.15	1 person classified as MIP after vomiting in disabled WC
14	1	2	1	11.07	11.09	11.17	11.21	
15	2	1	0	11.07	11.09	11.13	11.21	
16	3	6	0	11.07	11.09	11.12	11.21	
17	1	1	0	11.13	11.14	11.22	11.33	
18	2	6	0	11.13	11.14	11.19	11.24	
19	3	1	0	11.13	11.14	11.20	11.24	
20	1	11	0	11.21	11.25	11.30	11.30	
21	2	0	0	11.21	11.25	11.29	11.29	
22	1	0	0	11.31	11.32	11.35	11.35	
23	2	0	0	11.31	11.32	11.54	11.54	
24	1	10	0	11.40	11.41	11.49	11.49	
25	2	4	0	11.40	11.41	11.51	11.51	
26	1	9	0	11.40	11.41	11.57	11.57	
27	2	4	0	11.40	11.41	11.50	11.55	
28	1	2	0	11.46	11.48	11.57	11.37	
29	2	4	0	11.31	11.32	11.43	11.45	
30	1	2	1	11.31	11.32	11.38	11.38	
31	2	10	0	11.23	11.25	11.35	11.35	
32	1	2	0	11.23	11.25	11.31	11.37	

Table 4-1: Evacuation and Alarm Sequence Building M6

4.5 Summary and Conclusion

4.5.1 Building selection and details

Exploratory Case Study

The building details were described for Buildings 1-8 of the Exploratory case study by means of external elevations and text. The buildings ranged in height from 7 storeys to 45 storeys with the average height being 21 storeys. The evacuation strategies varied between controlled and uncontrolled. Height did not appear to determine this strategy as can be seen from the sequential strategies used in Building 1 of thirteen storeys uncontrolled strategy used in Building 3 of 34 storeys. Each of the buildings had two stairs and in general terms they were supplied with lighting at the landings. Attempts were made to re-access the buildings but this was not possible seeing some of the buildings had been extensively altered or permission was not granted. Buildings 3 and 7 were available and also had not been significantly altered. The stairwells were re-measured and templates completed. It was decided to demonstrate that these buildings were representative of the eight buildings in terms of their detail and evacuation strategies so that they could be integrated with the 2008-2010 case study in part as exemplar buildings in order to complete the longitudinal study[132] and also provide additional data for the factor analysis of stair design and environmental data as well as comparing trends from similar survey data.

2008-2010 Case Study

The building details for buildings M1 to M6 are described using floor plans and elevations (where available) together with detailed plans of the stairwells and stairs together with additional visual images where the taking of photographs was permitted. The range of buildings selected was similar to that of

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[132] Trends in impact of the contextual issues were compared with the equivalent ones from the 2008-2010 case study in Chapter 7.

the Exploratory case study so as to provide a similar range of extrinsic data. The height of the buildings varied from building M1 of ten storeys to M2/M6 which were in excess of thirty storeys. Given that one of the main outcomes of the Exploratory case study was an estimated descent performance limit or functional capacity of 25 storeys the average height of buildings M1-M6 needed to be similar so as to achieve a suitable distribution of distances to be traversed by the participants in the 2008-2010 trial evacuations. The average height was found to be 24 storeys. Seeing it was anticipated that the performance of 50% of the population would most likely decrease because of the increase in the number of functional limitations and the reduction in the level of fitness suggested by Pauls, Fruin and Zupan (2007) the selection was deemed to be satisfactory. None of the buildings examined had lifts that were suitable for occupant evacuation other than the emergency lifts that could be used by the firefighters to assist occupants who were unable to use the stairs. Building M6 was an example of where the evacuation planning incorporated the fire brigade assistance into their strategy.

4.5.2 Analysis and Results of trial evacuations

The results of the trial evacuations are presented in the Chapters 5-8.as follows:

- Exploratory case study data and considerations for comparison with 2008-2010 Case Study – Chapter 5
- 2008-2010 Delphi Group, Focus Group and Content Analysis Results – Chapter 6
- 2008 -2010 Main Case Study survey, observation and stair environment assessment plus triangulation schedules.

The results are presented with sections comprising discussions and summarised into findings in Chapter 8.

A STUDY OF THE PERFORMANCE OF OFFICE WORKERS DESCENDING MULTIPLE FLIGHTS OF STAIRS IN HIGH RISE OFFICE BUILDINGS IN TRIAL EVACUATIONS

HAMISH A/ MACLENNAN

Volume II of II

Ph.D. Thesis 2013

A STUDY OF THE PERFORMANCE OF OFFICE WORKERS DESCENDING MULTIPLE FLIGHTS OF STAIRS IN HIGH RISE OFFICE BUILDINGS IN TRIAL EVACUATIONS

Thesis submitted as partial fulfilment of Doctor of Philosophy
University of Salford
School of the Built Environment

Prepared by:
Hamish A.MacLennan

VOLUME II :
Results, Discussion, Conclusions and References

Chapters 5 - 9

2013

Chapter 5: The Exploratory Case Study

5.1 Introduction

This PhD Study comprises two integrated Case Studies. The first is known as the Exploratory Case Study and the second as the 2008-2010 Case Study. The component parts are outlined in Figure 5-1 below:

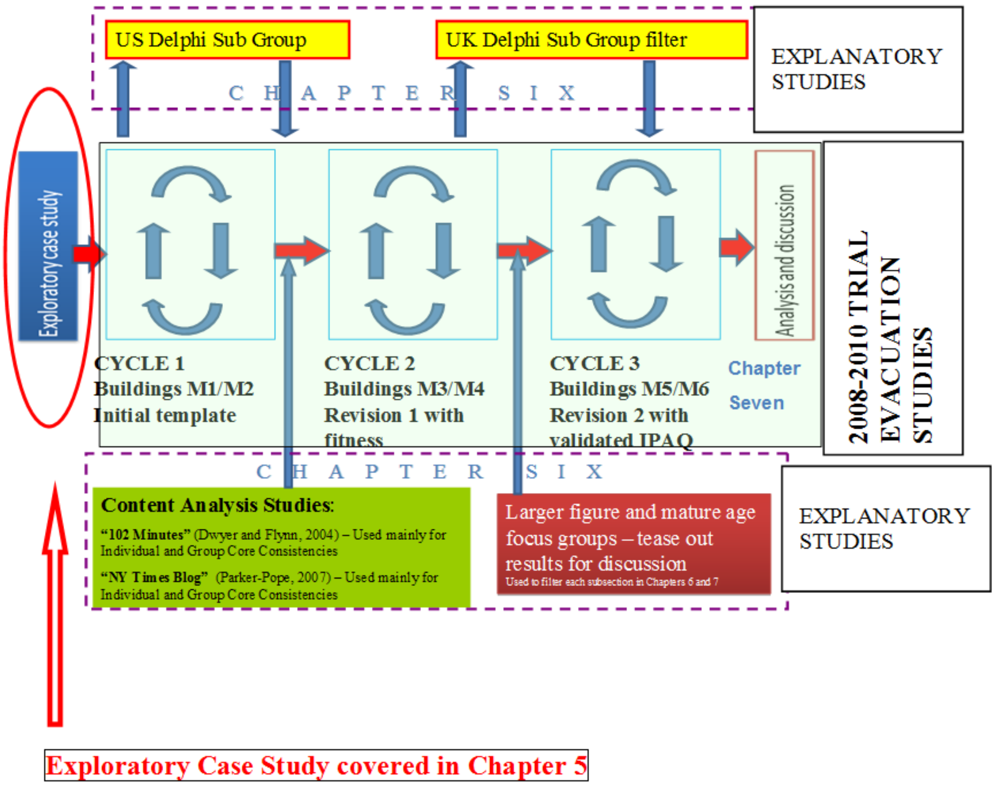

Figure 5-1: Relationship of Exploratory Case Study (Chapter 5) with main 2008-2010 Case Study presented in Chapters 6 and 7.

The Exploratory Case Study is an analysis of the data from a similar study of high rise office building evacuations by the author during the 1980's[133]

[133] The 1980 research project produced a set of data which will now be referred to as the "1980 Data-set".

as described in Chapters 3 and 4. The purpose of this Exploratory Case Study is to:

- To study individual performance in the descent of multiple flights of stairs in trial evacuations of high rise office buildings for comparison with the same task in the 2008-2010 case study[134]
- Highlight the intrinsic and extrinsic factors in the 1980's that formed the context of the Aim.
- Compare the Exploratory Case Study Outcomes with equivalent ones from the main 2008-2010 Case Study in Chapter 7 so as to be able to challenge or confirm the assertions of Pauls et al (2007) that the assumed changes in the characteristics of the general population require further changes in the design, use, care and management of high rise office building stairs and evacuation systems.[135]

Before proceeding any further, it is necessary to briefly define the scope of the 2008-2010 Case Study as shown in Figure 5-1. The 2008-2010 Case Study comprises the study of trial evacuations in six high rise office buildings (Building M1-M6)[136] as described in Chapter 4 using the methodology described in Chapter 3. The first part[137] of the 2008-2010 Case Study comprises:

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[134] In order to verify the claims of Pauls, Fruin and Zupan (2007) re the changed intrinsic characteristics of the general population

[135] Considered as longitudinal in the semse of the comparison of cases in terms of patterns (Hak and Dul, 2009) and also the entire PhD Study compares the performance of separate office populations so that generalisations can be made (Yin, 2009)

[136] Results for PDSA Cycles 1-3 (Buildings M1-M6) are presented in Chapter 7.

[137] Results for Delphi Group, Content Analysis and Focus Group Studies are presented in Chapter 6.

- Delphi Group consideration of the make up of which intrinsic and extrinsic factors they consider to be critical in the descent of high rise office building stairs and how occupant or individual performance can be predicted within this context.
- Content Analysis of occupant accounts of critical evacuation incidents to establish an inclusive occupant perspective as secondary data to further explain the context and impact of some of some of the extrinsic factors.
- Focus Group considerations of the make up of the contextual factors

Seeing a pluralist research method (Amaratunga et al, 2002) is being adopted for this case study the framework for the analysis is formulated by the Delphi and Focus Groups so that the results from the study of the trial evacuations in each one of the Plan-Do-Study-Act Cycles (PDSA) can be enhanced and further explained. The overall process together with where the component parts can be found is shown above in Figure 5-1. The Exploratory Case Study results are presented in this Chapter as a further analysis of some of the results from the 1980 Data-set. The findings will be summarised and presented on an Ishikawa Chart as this was the model used to interrogate the literature in Chapter 2. The outcome will be used to challenge and/or explain the findings from Chapter 6.

5.2 The Exploratory Case Study and the 1980 Data-set.

5.2.1 Limitations of the Exploratory Case Study for Analysis of Results.

One of the triggers for this PhD Case Study was the assertions made by Pauls et al (2007) that the fitness and health of building occupants have changed since the 1980's. The data from the author's 1980 evacuation research project has never been fully analysed and the results published[138]. These data are known as the 1980 Data-set. An analysis of this Data-set comprises the Exploratory Case Study as explained in the previous section.

The 1980 Data-set is only available in hard copy form (SPSS V2-1) so that the Exploratory Case Study Analysis is limited by these data. Coded survey responses were stored on magnetic tapes and these are no longer available. Responses coded by age, gender and BMI are not available. This imposes severe limitations on the outcome of the Exploratory Case Study. The hard-copy output was associated with a sample size of 780 occupants spread over eight buildings as described in Chapter 4.

In order to compensate for these limitations the Exploratory Case Study was expanded to include another similar study involving Pauls (1977) carried out by Beck (1977) for Health and Welfare Canada. The latter comprises three high rise office buildings. Although the Canadian Study (Beck 1977) did not deal directly with trial evacuations in the three Ottawa buildings surveyed it is a comparison between a set of office buildings utilising an approach where the main unit of analysis was the occupants. Such an approach is analogous to the case study approach as argued by Yin (2009). The statistical analysis was further enhanced by observation and expert opinion which resembles the pluralist approach often used in studies of human factors in the built environment (Amaratunga et al, 2002).

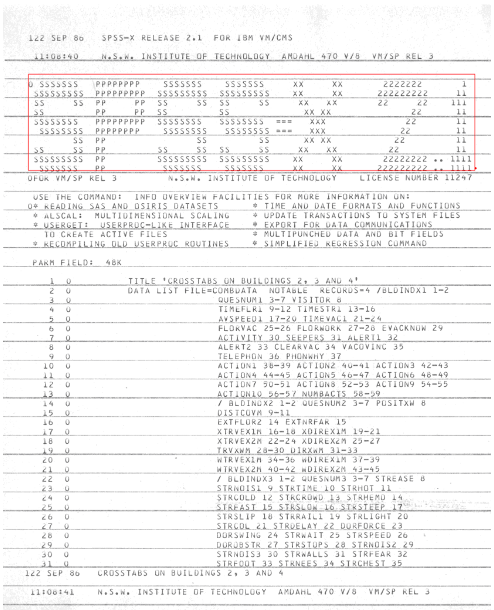
The limitations of the 1980 Data-set on the Exploratory Case Study will therefore be compared with the output from the Canadian Study (Beck, 1977) seeing similar research methods and buildings were used. Other similarities between the 1980 Data-set and the Canadian Study that support its inclusion are:

[138] The project was terminated due to the lack of resources and funding. All the survey data had been completed but had not been triangulated with the observations. Evidence of the studies may be found in MacLennan et al (1999) and Pauls (1985).

- Similar ageing rates of Canadian and Australian populations at the time (Rowland, 1991).
- Similar extrinsic factors associated with the buildings (stairwell construction, and management).
- The study was led by Pauls (1974) who was also a member of the 1980 Study Expert Group. The 1980 Study was based on it so that the cases within the Beck Study (1977) can be compared using the pattern matching technique (Hak and Dul, 2009)

5.2.2 The 1980 Data-set

A sample output sheet from one of the runs on the original Amdahl 470 mainframe computer in 1986 is included below as evidence of the source of the data for the Exploratory Case Study.



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 SS     SS  PP     PP  SS     SS  SS     SS     XX   XX        22     22   111
 SS         PP     PP  SS         SS             XX XX               22     11
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        SS  PP                SS         SS      XX XX            22        11
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 SSSSSSSSS  PP         SSSSSSSSS  SSSSSSSSS    XX     XX       22222222 .. 1111
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0FOR VM/SP REL 3         N.S.W. INSTITUTE OF TECHNOLOGY    LICENSE NUMBER 11247

 USE THE COMMAND:  INFO OVERVIEW FACILITIES FOR MORE INFORMATION ON:
0* READING SAS AND OSIRIS DATASETS        * TIME AND DATE FORMATS AND FUNCTIONS
 * ALSCAL:  MULTIDIMENSIONAL SCALING      * UPDATE TRANSACTIONS TO SYSTEM FILES
 * USERGET:  USERPROC-LIKE INTERFACE      * EXPORT FOR DATA COMMUNICATIONS
   TO CREATE ACTIVE FILES                 * MULTIPUNCHED DATA AND BIT FIELDS
 * RECOMPILING OLD USERPROC ROUTINES      * SIMPLIFIED REGRESSION COMMAND

 PARM FIELD:  48K

    1  0         TITLE 'CROSSTABS ON BUILDINGS 2, 3 AND 4'
    2  0         DATA LIST FILE=COMBDATA  NOTABLE  RECORDS=4 /BLDINDX1 1-2
    3  0                         QUESNUM1 3-7 VISITOR 8
    4  0                         TIMEFLR1 9-12 TIMESTR1 13-16
    5  0                         AVSPEED1 17-20 TIMEVAC1 21-24
    6  0                         FLORVAC 25-26 FLORWORK 27-28 EVACKNOW 29
    7  0                         ACTIVITY 30 SEEPERS 31 ALERT1 32
    8  0                         ALERT2 33 CLEARVAC 34 VACOVINC 35
    9  0                         TELEPHON 36 PHONWHY 37
   10  0                         ACTION1 38-39 ACTION2 40-41 ACTION3 42-43
   11  0                         ACTION4 44-45 ACTION5 46-47 ACTION6 48-49
   12  0                         ACTION7 50-51 ACTION8 52-53 ACTION9 54-55
   13  0                         ACTION10 56-57 NUMBACTS 58-59
   14  0                         / BLDINDX2 1-2 QUESNUM2 3-7 POSITXW 8
   15  0                         DISTCOVM 9-11
   16  0                         EXTFLOR2 14 EXTNRFAR 15
   17  0                         XTRVEX1M 16-18 XDIREX1M 19-21
   18  0                         XTRVEX2M 22-24 XDIREX2M 25-27
   19  0                         TRVXWM 28-30 DIRXWM 31-33
   20  0                         WTRVEX1M 34-36 WDIREX1M 37-39
   21  0                         WTRVEX2M 40-42 WDIREX2M 43-45
   22  0                         / BLDINDX3 1-2 QUESNUM3 3-7 STREASE 8
   23  0                         STRNOIS1 9 STRTIME 10 STRHOT 11
   24  0                         STRCOLD 12 STRCROWD 13 STRHEMD 14
   25  0                         STRFAST 15 STRSLOW 16 STRSTEEP 17
   26  0                         STRSLIP 18 STRRAIL1 19 STRLIGHT 20
   27  0                         STRCOL 21 STRDELAY 22 DORFORCE 23
   28  0                         DORSWING 24 STRWAIT 25 STRSPEED 26
   29  0                         DOROBSTR 27 STRSTOPS 28 STRNOIS2 29
   30  0                         STRNOIS3 30 STRWALLS 31 STRFEAR 32
   31  0                         STRFOOT 33 STRNEES 34 STRCHEST 35
 122 SEP 86    CROSSTABS ON BUILDINGS 2, 3 AND 4

  11:08:41    N.S.W. INSTITUTE OF TECHNOLOGY  AMDAHL 470 V/8  VM/SP REL 3
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The SPSS V2-1 output was rigorously interrogated using the same method proposed for the Canadian Study. The data from the 1980 Data-set was coded under the following headings based on the schedules presented in the Data-set prior to being regrouped in accordance with the classifications suggested by the Delphi Group in Chapter 6:

- Extrinsic 1 - stair environment and location
- Extrinsic 2 – stairs
- Extrinsic 3 – handrails, lighting and maintenance
- Extrinsic 4 - density - others
- Extrinsic 5 - delays – others
- Extrinsic 6 - group formation
- Intrinsic 1 – confidence
- Intrinsic 2 – ability
- Intrinsic 3 – fatigue and distance – preliminary analysis of Thesis Aim as stated in Chapter 1.

The above data is presented for all eight buildings (described in Chapter 4). This data is analysed in such a way that two exemplar buildings can be selected as being representative of the 1980 Data-set and will form the output from the Exploratory Case Study. The comparison with the results from the 2008-2010 Case Study may be found in Chapter 7.

5.2.3 Structure of Exploratory Case Study

The Exploratory Case Study Results are presented in parts:

- Part One: Content Analysis of 1977 Health and Welfare Canada.
- Part Two: Restructure and Analysis of the 1980 Data-set.[139]
- Conclusions for Chapter 5

[139] Analysed separately and then compared together – summarised in an Ishikawa Chart

5.3 Part One: Content Analysis of 1977 Health and Welfare Canada Study

An analysis was carried out of a report and statistics prepared by Beck (1977) for Health and Welfare Canada. Three of the five buildings presented in this report were selected because of their similarity to the eight buildings in the 1980 Data-set. The three buildings are high rise office buildings in Ottawa and the findings from the Canadian Study were presented in two tables (Table 5-1 and Table 5-2. The tables are provided from the original documents.

.Extrinsic Element	Jeanne Mance	Concord	Lasalle 2
No. Storeys	21	10	5
Clear Width of Stairs	881mm	907mm	1186mm
Stair Pitch *Measured:* *Level of significance for occupants:*	 37^0 *OK: Moderate significance (p<.05)*	 36^0 *No comment Moderate significance (p<.05)*	 35^0 *Not significant* *Moderate significance (p<.05)*
Tread /Going *Measured:* *Mean foot size:*	 267mm *300mm*	 267mm *300mm*	 280mm *300mm*
Riser *Measured:* *Trip hazard:* *Comments:*	 178mm *50X50 overhang* *Trip hazard*	 190mm *25X25 overhang* *Acceptable: D1/AS1*	 190mm *Open* *Trip hazard – D1/AS1*
Handrail *Height:* *Graspability:*	 1067mm *OK – moderately significant (p<.05)*	 1067mm *Poor – moderately significant (p<.05)*	 1067mm *OK – moderately significant (p<.05)*
Lighting / Visibility	*OK – highly significant (p<.001)*	*Yes but poor illumination - – highly significant (p<.001)*	*OK as fluro. Supplemented by natural light – highly significant (p<.001)*
Distraction	*No comment and not significant*	*No comment and not significant*	*No comment and not significant*
Conspicuity/ Legibility	*OK but not significant as p=.08*	*No contrast but not significant as p=.08*	*No comment but not significant as p=.08*
Ventilation	*OK – highly significant (p<.001)*	*Not satisfactory – highly significant (p<.001)*	*OK – highly significant (p<.001)*
Maintenance	*No comment – highly significant (p<.001)t*	*Unclean – highly significant (p<.001)*	*Clean- highly significant (p<.001)*
Temperature	*OK and reasonably significant (p<.01)*	*Too hot and cold - reasonably significant (p<.01)*	*No comment - reasonably significant (p<.01)*
"Locked in"[140]	*No - highly significant (p<.001)*	*Yes - highly significant (p<.001)*	*No comment - highly significant (p<.001)*
General safety	*No signage but not significant as p=.08*	*Yes concerned - but not significant as p=.08*	*Yes concerned - but not significant as p=.08*
Orientation and knowing location	*No signage - moderately significant (p<.05)*	*No view of floor or signage - moderately significant (p<.05)*	*Could locate floors through door viewing panel and signage - moderately significant (p<.05)*

Source: Beck, R.J., (1977), *Health Impacts of the Use, Evaluation and Design of Stairways in Office Buildings,* Health and Welfare Canada, Health Programs Branch, Health Consultants Directorate, Health Facilities Design. **:**

Table 5-1: Interaction of Occupants with Extrinsic Stair Variables -Beck (1977)

140 Can trigger agoraphobia (NCBI, 2012) which in turn can lead to visually induced postural sway (Redfern et al, 2007)

Intrinsic Elements	Frequency (%age)	Comments
Age		
18-30	58.6	
31-40	21.8	
41 plus	19.6	*This percentage has increased in the general population since 1977. It is over 44% in NZ in 2007 (Wilson et al (2007)*
Gender		
Male	49.25	
Female	50.75	
Fitness attitude		
(5) very conscious (4) conscious but only walk (3) somewhat conscious but most likely lazy (2) conscious and no action (1) no answer	(5) = 39.8 (4) = 44.8 (3) = 12.7 (2) = 2.5 (1) = 0.2	*In the sample 29.8% reported they were involved with a government fitness programme.*
Reasons for not using stairs		*48,5% excluded themselves from normal stair use (intercommunication)*
Health conditions including physical impairment, reduced vision and other	4.0	
Vertigo and dizziness	2.7	
Fear of falling	1.5	*2.5% of the population surveyed had fallen and hurt themselves. A further 11% had stumbled.*
Stairs unpleasant	8.2	*Much of this is attributed to the stair environment and could be remedied by Management*
Job does not permit it	15.4	
Takes too long	7.2	
Don't know	7.6	

Source: Beck, R.J., (1977), *Health Impacts of the Use, Evaluation and Design of Stairways in Office Buildings,* Health and Welfare Canada, Health Programs Branch, Health Consultants Directorate, Health Facilities Design.

Table 5-2: Intrinsic Factors from 1977 Canadian Study

The two exemplar buildings that will be selected from the analysis of the 1980 Data-set in the next section are Buildings 3 and 7 as explained in Chapter 4. The slope of the stairs in Table 5-1 for the three buildings from the content analysis of the Canadian Study is similar but the treads are slightly wider (6.4%) thereby decreasing the toe overhang from 50mm to 33mm. A 50mm toe overhang (250mm tread) is unacceptable as it usually precludes the occupant from facing "front on" in the direction of descent (Roys, 2006) increasing the risk of falling.

The height of the handrail is 202mm higher than the minimum 865mm in the Australian Codes of the day and yet the next section will show that this height did not affect the responses extracted from the 1980 Data-set.

Two significant psychological factors show up in Table 5-1 and that is the fear of being locked in (NCBI. 2012) ($p<.001$) and the resulting moderate significance ($p<.05$) of wayfinding and signage. Management can deal with both of these issues. They should also be concerned with the cleanliness and maintenance of the stairs as highlighted in Table 5-1. These aspects are of concern to the occupants ($p<.001$) as compared with general level of safety which was not significant to the occupants ($p<.08$). The possible impact of the above factors is that they may have deterred the occupants from using the stairs for intercommunication which constitutes additional exercise.

Table 5-2 shows that 19.2% is similar for the 40+ age group to that of the 1980 Study (Rowland, 1991), so that comparisons can be made. The same can be said for gender (Rowland, 1991). The response in Table 5-2 unfortunately is aggregated across all three buildings but it does deal with the aspect of fitness. Given that 80.4% of the sample was below 40 years of age the anticipated level of fitness is not reflected in that only 39.8% of the sample was "conscious of fitness" and only 29.8% were enrolled in a government approved fitness programme. This means that 10% were enrolled in private programmes, undertaking a structured exercise programme or believe that an intense walking programme qualifies. A further 44.8% did do some form of walking and were somewhat conscious of fitness. 48.5% of the respondents excluded themselves from using the stairs due to the following:

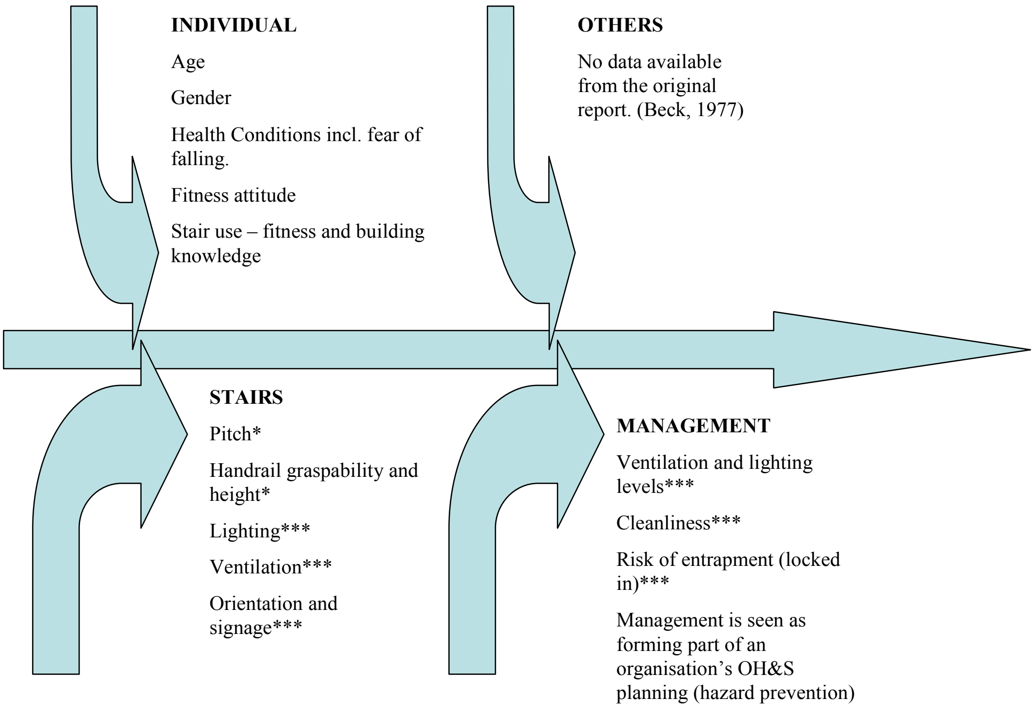
- 8.2% said the stairs were unpleasant.
- 15.2% said that their job prevented them from using the stairs i.e. Time lost in negotiating the stairs as well as restrictions from management.

Fitness is stair use (Pauls et al, 2007) and it is important to include it in the analysis of the 1977 Canadian Study as the data from the 1980 Data-set did not specifically include it. Following on from the above a profile of the functional limitations of the respondents that excluded them from using the stairs (Table 11) is outlined below:

- 4% due to health conditions including limited mobility, reduced vision, and other as compared with 10.2% in Table for the exemplar buildings in Part Two of the Exploratory Case Study
- 2.7% due to vertigo and dizziness compared with 2.7% in Table 5-3 for the exemplar buildings in Part Two of the Exploratory Case Study.
- 1.5% due to fear of falling (Table 5-3). No comparison was made in this regard as balance may be synonymous with vertigo and dizziness.
- 1.9% for general fatigue as compared with 3% on average for the exemplar buildings in the 1980 Study excluding the "slight' responses (Table 5-3)

In order to view these data in context Rowland (1991) shows that in Australia in 1981 6.32% of the population (all age groups) had some kind of impairment that would have most likely excluded them from the use of stairs. The 10.2% for "Part Two" of the Exploratory Case Study exemplar buildings in

Table 5-3 could therefore be considered to be reasonably significant except that this is not reflected in other results that are discussed in the next section.



**p<.05 is moderately significant; **p<.01 is reasonably significant and ***p<.001 is highly significant. Taken from Chi Squared analysis.*

Figure 5-2: Ishikawa Chart Summary of Results of Content Analysis of 1977 Study.

Figure 5-2 above summarises the results for the Canadian Study (Beck, 1977) via the Ishikawa Chart Model that was used to interrogate the literature in Chapter 2. Each branch of the Chart has been populated with the findings summarised above and set out in Table 5-1 and Table 5-2. The main difference with the spine and the intent of the Canadian Study to that from the Delphi Group described in Chapter 6 is that the Aim of the Canadian Study was whether or not the occupants of the three Ottawa office buildings were "prepared to use the stairs". This cannot be confirmed for certain as the data does not define the significance of the relationship between fitness and "preparedness to use the stairs". This relationship certainly underpins the PhD Study Aim and Objectives as well as the misgivings raised by Pauls et al (2007) in the application of data gathered during the 1960's and 1970's to current evacuation and stair use studies. The analysis of the Canadian Study therefore provides significant results to compare with the results of the analysis of the 1980 Study presented below in the next section.

5.4 Part Two of the Exploratory Case Study – Restructure and Analysis of data from the 1980 Data-set.

The tables from the original SPSS V2-1 hard copy have been restructured for ease of pattern matching as follows:

- Where the scale is "*Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree*" the scale is condensed to "*Agree – Neutral – Disagree*"
- Where the scale is "*An extreme degree – very much – moderate – slight – not at all*" the scale is condensed to "*extreme/moderate – slight – not at all*"

The results of the Content Analysis presented in Table 5-3 (over page) will be discussed under each group of factors (in Section 5.2.2).

Factor / Core Consistency	Variable	Building 1: 13 (121)			Building 2: 17† 114)∞			Building 3: 33† (150)∞			Building 4: 45† (92) ∞			Building 5: 7† (32) ∞			Building 6: 19† (46) ∞			Building 7: 20† (95) ∞			Building 8: 19† (54) ∞		
		Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral/ Slightly	Disagree/ Not at all
Extrinsic 1	Stair easy to find	86.8	3.3	9.9	92.9	3.3	3.5	95.3	3.3	1.3	95.6	2.2	2.2	98.8	0	1.2	91.3	6.5	2.2	94.7	3.2	2.1	94.1	2.4	3.6
	Stair was too hot	9.4	23.9	66.7	24.7	31.2	43.7	10.0	33.3	56.7	16.2	30.1	53.8	3.7	37.5	58.7	0.0	20.0	80.0	10.5	34.7	54.7	11.9	26.2	61.9
	Time in stairs too long	32.5	23.3	44.2	41.6	25.7	32.8	22.4	27.2	48.6	22.1	29.7	47.3	17.3	17.3	65.4	20.0	26.7	53.3	31.9	28.7	39.4	32.2	29.8	38.0
Extrinsic 2	Stairs too steep	19.0	22.3	58.7	12.6	32.4	55.0	7.4	25.3	67.4	5.4	23.9	70.7	4.9	23.7	71.3	4.4	15.6	80.0	5.3	22.1	72.6	21.7	24.1	54.2
	Apprehension about safe footing on small treads	18.1	20.5	61.4	12.5	31.3	56.3	11.7	20.5	67.8	16.3	20.7	63.0	7.3	13.6	79.1	9.3	20.9	69.8	9.3	18.8	71.9	13.4	22.5	58.7
	Steps too slippery	18.5	16.0	65.5	6.3	18.9	74.8	2.0	15.3	82.7	2.2	10.8	87.0	3.5	16.0	80.3	0.0	15.2	84.8	3.2	13.7	83.1	7.2	15.4	87.4
Extrinsic 3	Used handrail in descent	30.6	21.5	47.9	31.6	17.5	50.9	20.4	19.0	50.6	72.1	14.0	14.0	28.4	23.5	48.1	32.5	9.3	58.2	23.7	20.4	55.9	24.4	23.1	52.5
	Handrail awkward to use	NA	NA	NA	9.1	30.0	60.9	17.7	22.1	60.2	8.7	14.0	77.3	6.2	18.5	71.3	8.7	10.9	80.4	10.6	17.9	71.5	4.9	23.2	71.9
	Stair lighting inadequate	14.9	20.7	64.4	4.5	21.6	73.9	2.0	10.8	87.2	6.5	9.8	83.7	5.0	14.8	80.2	2.2	15.2	82.6	5.4	14.9	79.7	8.4	9.5	82.1
	Maintenance is inadequate	21.5	34.7	33.8	25.2	41.4	33.4	15.3	32	52.7	17.2	29.0	51.8	13.9	34.2	51.9	2.2	35.6	62.2	14.1	32.6	53.3	28.6	25.0	46.4
Extrinsic 4	Stair was uncomfortably crowded	18.1	18.2	63.6	13.7	26.4	49.9	15.5	22.7	61.0	4.4	15.2	80.4	8.6	18.5	72.7	8.7	15.2	76.1	16.9	20.0	63.1	16.0	19.0	65.0
	Stair was not wide enough	25.6	14.9	59.5	29.7	21.6	48.7	19.7	17.1	66.2	17.3	17.2	65.5	10.1	11.4	78.5	8.7	13.0	78.3	24.3	18.9	56.8	20.2	17.9	61.9
Extrinsic 5	Delay due to slow movers in group	18.9	23.8	57.4	37.9	23.9	37.2	24.0	38.0	38.0	16.1	23.7	60.2	10.7	23.7	65.6	15.2	21.7	63.1	31.6	27.4	41.1	13.4	28.0	58.6
Extrinsic 6	Entered stairs with a group	34.4	12.3	53.3	57.0	14.9	28.1	52.5	21.8	25.7	44.4	18.9	36.8	31.2	22.5	46.3	46.3	9.5	45.2	33.7	20.0	46.3	42.5	15.0	42.5
	You knew the others close to you in the stairs	72.4	13.3	14.3	88.9	7.9	13.2	78.3	10.9	10.8	76.1	13.0	10.9	75.4	17.1	8.5	66.6	16.7	16.7	67.4	14.7	17.9	73.7	15.0	11.3
Intrinsic 1	Apprehension about personal safety	14.0	28.7	57.3	11.6	30.4	58.0	5.5	19.5	75.0	15.1	26.8	58.1	6.9	10.1	85.0	16.4	16.3	67.3	11.5	22.9	65.6	17.4	20.0	62.6
Intrinsic 2	Weakness/pain in knees	5.7	7.4	86.9	17.0	22.3	60.7	10.2	23.8	66.0	21.5	39.8	38.7	3.7	3.7	92.6	16.3	14.0	69.7	3.1	10.4	86.5	12.4	8.7	78.9
	Discomfort in chest	3.3	3.3	93.4	0.0	5.4	94.6	1.4	6.8	91.8	3.3	4.3	92.4	1.2	2.5	96.3	0.0	4.7	95.3	2.0	2.1	95.9	1.2	3.7	95.1
	Fatigue generally	3.2	11.5	85.3	4.5	17.1	78.4	2.7	16.2	81.1	5.4	26.9	67.7	2.5	4.9	92.6	0.0	18.5	81.4	3.0	3.2	93.8	5.0	11.2	83.7
	Dizziness/ balance	3.2	11.5	85.3	4.5	17.1	78.4	2.7	16.2	81.1	5.4	26.9	67.7	2.5	4.9	92.6	0.0	18.5	81.4	3.0	3.2	93.8	5.0	11.2	83.7
Intrinsic3	Fatigue vs. distance traversed #	R^2 = 0.76*	**REGRESSION SHOWN USING MEASURES FROM BUILDINGS 3, 4 AND 2 – SEE TEXT**																						

Denotes Exemplar Building Nos. 3 and 7 – Data for Charts for being moderately significant; * *p<.05 # estimate only;* † *Denotes number of storeys;* ∞ *denotes number in sample =N*

Table 5-3: Table of Frequencies for Part Two of Exploratory Case Study (assembled from 1980 Data-set)

5.4.1 Extrinsic One: Stair Environment and Location

Knowledge about the location of the fire stairs in high rise office buildings does not necessarily imply that occupants have used and are familiar with the stairs and stairwells. The data confirmed this via responses that in many instances the fire wardens forming part of the building's emergency control organisation[141] did direct the occupants to the fire stairs as the pattern is reasonably consistent across all eight buildings in terms of the major percentage in each building agreeing that the location of the stairs was familiar (N=784). This ranged from the lowest for Building 1 of 86.8% to the highest of 98.8% for Building 5. The two exemplar buildings (3 and 7) which are highlighted in orange in Table 5-3 represent the mean of this range being 95.3% and 94.7% respectively[142.]

The analysis of the 1977 Canadian Study (Beck, 1977) raised the issue of ventilation to the stairwell. The level of concern of the occupants with this issue was found to be highly significant ($p<.001$). Although it appears that the results were aggregated in this instance in Table 5-2 this may not be the case because of the large percentage of respondents across all eight buildings who adopted a neutral stance. Agreement with the lack of ventilation varies from 0% for building six to 24.7% for building two. Respondents who did not have any difficulties range from 44% for building two to 79.6% for building eight. The stairs in building five only connected five storeys whilst those in building four connected some forty five floors. Response to ventilation rates appear to be directly connected to physical exertion and the level of maintenance. It is the latter where the significance may match the equivalent results in Table 5-2. Once again the two exemplar buildings are representative as they follow the same pattern and range of responses.

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141 Emergency Control Organisation is a term used in Australian Standard AS 3745-2010.

142 Justification statement for Exemplar Buildings 3 and 7 being representative in bold italics.

The pattern of responses for the time spent in the stair being too long is reasonably consistent ranging from 20% for Building 1 to 41.6% for Building 2 for those in agreement and from 32.8% for Building 2 to 65.4% for Building 5 for those who disagreed. Buildings 2 and 5 are two buildings that do not really follow the pattern as closely as the others. This can be explained as follows:

- There were delays in going down the stairs in Building 2 according to observation notes attached to the original data-set and this is also confirmed to a reasonable degree by the high proportion of respondents who agreed that there were delays in the stairs (37.9%).
- Building 5 only contained some seven storeys and was evacuated in less than 10 minutes which matches the low percentage of respondents who agreed with the time being too long as compared with the majority who disagreed (65.4%).

The two exemplar buildings are representative of the eight taking into account that they follow the pattern of responses where there was a greater amount of disagreement (39.4-48.6%) than agreement (22.4-31.9%). Further details are available in Appendix A5.[143]

5.4.2 Extrinsic Two: The Stairs

Roys (2006) showed that it was the width of the treads that was the critical factor in maintaining a "front-on" stance when going down stairs. Others did consider the pitch of the stairs (Startzell, 2000 and Riener et al, 2002). The pitch in Buildings 1-7 varied between 35^0 and 37^0.The occupants who were generally satisfied with this "slope" varied from 54.2% for building eight, to 80% for building six . Those who had the opposite view varied from 4.4% for building six to 21.7% for building eight. It should be noted that out of all eight buildings building six had the lowest pitch. ***Buildings 3 and 7 each had a pitch of*** 37^0 ***and***

[143]Justification argument for Buildings 2 and 7 being representative are in bold format

a similar pattern of responses from agreement to disagreement. They are representative of the eight buildings. The only comparative guide here is that according to Rowland (1991) 6.3% of the population had some kind of functional limitation which generally agrees with the response pattern. It could therefore be argued that the pitch is a significant issue generalising from the analysis of the Canadian Study (Beck, 1977). The patterns are discussed further in the Appendix A5.

Returning to the finding of Roys (2006) concerning the width of stair treads, the results in Table 5-3 do not appear to correspond with those who were not apprehensive about going down stairs with small treads varying from 71.9% in building seven to 56.3% in building two. In both instances the width of the treads was 250mm. A recent study carried out by the author on outdoor steps in the United Kingdom in 2009 of a sample of stair users (n=690) whose mean age was 66.7 years showed the length of the mean male shoe was 300mm (MacLennan, 2011). In 1981 the same sample would have had a mean age of 38.7 years so that a significant percentage of the sample in the 1980 Data-set according to Rowland (1991) would have had the same size feet. Those who were apprehensive about the small treads varied from 18.8% for building 8 to 7.3% for building 5.

In terms of the response pattern across all eight buildings and even including the "slight" response, Buildings 3 and 7 fall well within the range and also have 250mm wide treads which would not support a front-on stance for 50% of the population as demonstrated above and in the Appendix A5.

Slippery stairs[144] were shown to be of concern in the Content Analysis of the Canadian Study and this was highly significant (see; Table 5-2 p<.001). The construction material and riser/tread configuration was exactly the same as the Buildings 3 and 7. . The level of maintenance in some buildings was as high as 26% and yet this is not reflected in the pattern in Table 5-3 for slippery steps. The state of the stair tread surfaces at the time of each trial evacuation for

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[144] Slippery as ststed in questionnaire response and significant in terms of safe foot placement.

buildings one to eight was that they were free of debris and other irregular surface materials.

Buildings 3 and 7 are suitable as exemplar buildings as they fit within the range of responses and follow the same pattern.

5.4.3 Extrinsic Three – Handrails, Lighting and Maintenance

The apparent pattern in handrail use varies from 72.1% for building four where 50% of the population descended through more than 40 storeys to the next of 31.6% for building two which was 17 storeys in height. The stair geometry of the two buildings was the same. A possible argument is that a partial evacuation was involved in building four so that descent speeds were unconstrained. Each of the floors between levels 40 – 45 evacuated in groups assembled by the fire wardens on each level before entry. They descended in groups so that it is possible that "slow movers" had to speed up to keep up with the group as the rear of each group comprised a stair warden who made certain the group "stayed" together. The group dynamics were recorded by three observers, one of whom was the author who entered from level 45. The speed of descent exceeded 0.5m/sec on average. The differences between the exemplar buildings and building four can be explained by the distance travelled. It is therefore argued that handrails are used for support and as a means of maintaining balance and that this is a function of the distance to be travelled and the occupant's functional limitations. If fatigue is included loosely as a functional limitation then fitness may be involved as well. There is a strong relationship here with the findings from the Content Analysis of the Canadian Study. Once again ***Buildings 3 and 7 can be used as exemplar buildings as the pattern of handrail use fits within the range of the eight buildings from agree to disagree in*** Table 5-3**.** Further details may be found in Appendix A5.

Figure 5-3 shows a typical handrail detail that would difficult to grasp (Roys, 2006; Aldersen, 2010; Templer, 1992 and Archea et al, 1979).

Respondents as indicated in Table 5-3 who had no problems with the handrail in terms of rail section and height varied from 60.9% for building two to 80.4% for building six (average across the eight buildings of 70.6%). The contrary view varied from 4.9% for building eight to 17.7% for building three with the average across all eight buildings being 8.8%. Given the number of people who actually used handrails averaged 32.2% across all eight buildings it would appear reasonable to argue that the handrails were considered to be adequate. Given the body of evidence available from the research as represented by Alderson (2010) handrails will continue to be critical and recommended sections should still be adopted. It should be noted here that the Content Analysis of the Canadian Study found that the handrail graspability and height were moderately significant ($p<.05$). All the heights were the same being 1067mm and yet the performance of the handrails in one of the buildings was poor. This once again was most likely due to the level of maintenance, and could represent some of the variation for Buildings 3 and 7 shown in Table 5-3. The handrail height in the exemplar buildings was less than 900mm and yet the occupants were still basically satisfied. ***The results shown for the exemplar buildings are therefore representative of the eight buildings in the follow the pattern of response and are close to the mean.***

Figure 5-3: Typical example of handrails from Buildings 3 and 7 – rectangular profile and poor graspability.

Table 5-1 shows that the level of lighting is a significant factor in safe stair climbing (*p<.001*). The inadequacies expressed in Table 5-3 were most likely due to a lack of maintenance as demonstrated by the negative responses for cleanliness and ventilation. Table 5-3 shows that the respondents who agreed that the lighting was inadequate form a clear pattern varying from 2.2% for building six to 14.9% for building one, the average being 6.3%. There appears to be a possible link for building one with the level of maintenance seeing Table 5-3 shows that 21.5% of building one respondents agreed that the maintenance was inadequate. The overall level response across all eight buildings for the above is 18.3%. There is a similar pattern in the responses on the agreement and non agreement response pattern between the level of maintenance and the performance of the lighting except that there is an increase in the neutral position of the respondents of 14.8% for lighting as opposed to 33.2% for maintenance. There appears to be a link for building six in that only 2.2% of the respondents thought that the level of illumination and the maintenance was unsatisfactory. Positive responses varied from 64.4% for building one to 87.2% for building three with the overall level being 78.9%. Table 5-1 showing the results of the extrinsic elements in the Canadian Study reveal that two of the buildings had adequate lighting and one building did not. The pattern is similar between the two studies so that there is no reason for the level of significance not to be as well especially when there is a similar pattern with maintenance. This type of claim can be made via pattern matching (Hak and Dul, 2009). ***Buildings 3 and 7 fit within the above pattern in terms of the range between agreement and disagreement.***

Table 5-3 shows that a significant percentage of respondents from all eight buildings adopted a neutral stance on stair maintenance, varying from 25% for building eight, to 41.4% for building two. The majority of the respondents across the eight buildings thought that the maintenance was adequate with the overall position being 48.5% varying from 33.3% for building two to 63.3% for building seven. Those who thought that the maintenance was inadequate varied from 2.2% for building six to 28.6% for building eight. This shows the same pattern as the results of the Content Analysis of the Canadian Study in Table 5-1. The link between the lack of maintenance and the poor performance of lighting[145] is also common between the studies in Sections 5.3 and 5.4. ***It should also be noted that the response pattern for the two exemplar buildings is representative.***

5.4.4 Extrinsic Four: Density and Others

Density as shown in Chapter 2 is represented by "Levels of Service" where the density increases between Levels "A" to "F" (Fruin, 1987). People need personal space (Fujiyama, 2005) which may be connected with phobias or fears as will be shown in the Focus Group Study results in Chapter 6 and is discussed in Chapter 2. Occupants can still estimate the stairwell as being congested if they are held up by slower movers in front of them in a "platoon"

[145] According to survey respondents in each case

(Templer, 1992). This scenario was observed extensively in Building 4 with sequential groups following each other over a total of 40 levels.

In Table 5-3 the overall level of those who did not have an opinion on crowding represented 20% of the sample whilst those who thought that the stairs were not crowded varied from 50% for building two to 80.4% for building four. This agrees with the observer comments for the same building. The mean response across all eight buildings was 64.2%. Occupants with a counterview varied from 18.2% for building one to 4.4% for building four. Once again the response for building four is supported by the observations and the 4.4% may quite well have been those with either phobias, requiring additional personal space or where they estimated five levels of people descending together as representing a crowd. Any "crowding" most likely was attributed to "platooning" (Templer, 1992). Occupants from building one did experience delays due to deferment behaviour at stair entry points but once again stair entry only occurred over a small number of levels due to the large number of car parking levels. Group sizes were small as the pattern of stair entry was uncontrolled on each level.

The pattern in Table 5-3 is representative for the eight buildings varying from 62 to 63.2% for buildings three and seven for those who did not think that the stairs were crowded and from 15.3% to 16.9% for buildings three and seven who had a counter view. In each instance the exemplar building responses were slightly in excess of the overall level across all eight buildings. Observer comments for building three shows that the building evacuation time was some thirty three minutes and was efficient. Any uncomfortable crowding was most likely due to the "platooning" (Templer, 1992) caused by deferment merging behaviour similar to that observed by Boyce et al (2009).

Stair width is seen as being a crucial issue in current research (Peacock et al, 2009) especially in terms of having the opportunity to overtake. Templer (1992) argues with this on the basis of the space occupied by the group and the permeability of that "territory" (Lindskold et al, 1976).Table 5-3 shows between 11.4% of those respondents on building five to 29.7% of those on building two did not have an opinion one way or another. No data is available for descent speeds or the number of slow movers other than where for all eight buildings more than 40% of respondents experienced some type of delay**.** Groups were also formed extensively and data is available showing that no overtaking occurred**.** All the stairs across the eight buildings had a clear width in excess of 1000mm which is now not considered to be sufficiently wide enough for counter-flow due, for example, to fire-fighters. In Table 5-3 those respondents who did not think that the stairs were wide enough varied from 8.7% for building six to 29.7% for building two. 25.6% and 24.3% agreed for buildings one and seven. The overall position across all eight buildings in this regard is 20.7%. Counter-flow due to fire fighters did occur in buildings four, one, two and seven. The response for building two can be enhanced via counter-flow observations as can building seven and one. Seeing there were no over-takers and responses in Table 5-3 show that about 48% of respondents across all eight buildings experienced some sort of delay, it can be argued that if the stairs had been wider that there would have been room for slow movers to rest or faster movers to overtake. The impact of groups would be the constraint on this argument.

The width of the stairs in the Exploratory case study was 1020mm and most people were satisfied with this width. Delays due to counterflows did not draw negative responses. This was not the case in the 2008-2010 case study as will be shown in Chapter 7.

The stairs in the exemplar buildings three and seven were 1000mm in clear width. 19.7% of respondents for building three and 24.3% of respondents for building seven agreed that this measurement was too narrow. ***The buildings are therefore representative including the impact of the counter-flow of fire fighters in building seven.***

5.4.5 Extrinsic Five: Delays and Others

Referring to Table 5-3 the number of occupants who did not experience any delays was the majority across all eight buildings. The response pattern was also similar. There was a slight difference for one of the exemplar buildings (No.3) where 38.0% only experienced slight delays and this was the same as for those who did not experience any delays. Building 7 shows that 41.1% did not experience any delays compared with 27.4% with a slight delay. Delays due to others in an occupant's group varying from slight to an extreme degree vary from 62.8 % in building two to 35% in building five. The delays due to slow movers in groups are significant in terms of frequency. 62.0% of respondents in building three experienced some sort of delay due to slow movers in their group and 59% in building seven. This shows that delays within groups are significant in terms of frequency. The exemplar buildings three and seven involve 36 and 20 storeys of evacuation respectively. Table 5-3 does not reveal any set patterns or trends based on storey height or distance traversed. ***Buildings 3 and 7 are therefore representative.***

5.4.6 Extrinsic Six – Group Formation and Behaviour

Group formation and behaviour is crucial to the objectives of the thesis set out in Chapter 1 in terms of the formation of groups. A content analysis of a study by Dwyer and Flynn (2004) in Chapter 6 shows the extent of group formation in the use of stairs for the evacuation of Towers 1 and 2 of the WTC 9/11 incident. The group is exemplified by a majority behaviour type which is altruistic (Fahy and Proulx, 2005). This altruistic behaviour[146] also underpins the practice of deferment in merging in some instances at stair entry points being one of the patterns described by Boyce et al (2009).Table 5-3 shows that more than

[146] Altruistic behaviour can be measured by survey and content analysis of emergency incidents where people have put others before themselves (Zmud, 2007). It can b compared with the frequency of aggressive behaviours such as is demonstrated in the NY Times Study (Parker-Pope,

47% of respondents across all eight buildings made an effort to enter the stairs as part of a group. This effort varied from 46.7% in building one to 74.3% in building three. The overall position across all eight buildings was 60.6%. This result is significant in that it represents nearly two-thirds of the aggregated sample (n=770).

Buildings three and seven being the exemplar buildings differ by about 20% varying from 73.5% for three to 53.7% for seven which is relative to the overall position of 60.6%. It is therefore representative for inclusion in the 2008-2010 Study in Chapter 7.

The use of Buildings 3 and 7 as exemplar buildings is further supported by the response of those known to the respondents within the stairwell. 91.9% of the respondents knew the others around them in the stairs for building three and 82.1% for building seven with the overall position for all eight buildings being 87.3% (Table 5-3). The degree of pattern matching across all eight buildings confirms that the effort of entering as a group can be generalised for evacuations in the 1980's.

5.4.7 Intrinsic One: Confidence

57.4% of the respondents taken across all eight buildings (Table 5-3) were reasonably confident with going down the stairs even with predominance of narrow treads, slopes of between 35^0 – 37^0, and loss of stair conspicuity due to the extent of group formation discussed above. This varied from 75% for building three to 57.3% for building one. Conversely there were a significant percentage of occupants (25% for Building 3 and 42.7% for Building 1 who were not so confident. The significance is difficult to argue even with the further amount of support provided by the Canadian Study (Beck, 1977) which was moderately significant ($p>.05$).

The pattern for the exemplar buildings in Table 5-3 for the above moderate level of confidence shows that 25% of the respondents from building three and 34.4% from building seven were concerned about their general safety.

Records of on site assessment reveal steps that were well lit but not really legible in terms of the definition of each step. The treads are only 250mm wide and the slope of the stairs 37^0 so that these may contribute to the concern. ***The two exemplar buildings are representative of the eight and also reflect the analysis of the results in the previous paragraph.***

5.4.8 Intrinsic Two: Functional Limitations

The functional limitations dealt with in this section are:

- Musculo-skeletal conditions in the lower leg / knees
- Chest or respiratory condition
- Fatigue rating
- Dizziness and vertigo - stability

Table 5-3 shows the details. The knee condition appears to worsen as the number of storeys traversed increases where density is not a factor. Density can mask by reducing the descent speed (Fruin, 1987 and Galea et al, 2008). ***Building 3 is representative of the above but building seven is not***. It does still fit within the range when compared with Building 2. This can be explained as density did reduce the descent speed as reported by observers in this building so that the pattern of responses can be affected. See Appendix 5 for further details.

Table 5-3 shows that less than 8.2% of respondents experienced some sort of discomfort. This falls within the range of impairments presented for that period by Rowland (1991) of 6.3%. The impact of distance on chest discomfort is somewhat marginal compared with knees (Building 4 is 27% greater in distance traversed and a reduction in number of chest complaints). ***The exemplar buildings follow the pattern for the other six buildings*** with Building 3 being 8.2% for any type of discomfort (upper range) and similar to Building 4 in terms of distance travelled and 4.1% for Building 7 which is similar to Building 6 in terms of distance.

Table 5-3 generally shows an increase in fatigue for Building 4 (32.3%) as compared with Building 3 which is 18.9%. The latter is similar to Buildings 6 and 8 which are approximately 13 storeys less in height. A regression analysis of available data from the 1980 Study confirms the above analysis where only 60% of the variance can be accounted for and that building three has the same level of response as those for buildings one, two, six and eight.

The Exemplar buildings are therefore reasonably representative except for Building 7 which has the characteristics of an outlier relating to fatigue. Outlier characteristics relating to fatigue and functional limitations are important because they are self reported. This method of collecting health condition and fitness data was criticised by the UK Delphi Sub Group so that the inclusion of an outlier characteristic in an exemplar building for comparison with the 2008-2010 Case Study is still acceptable. A further regression analysis relating occupant estimated descent coping ability shows that there is a sudden increase in this measure for > 50% of the population generalised across buildings 2-4 as shown in Figure 5-4 below:

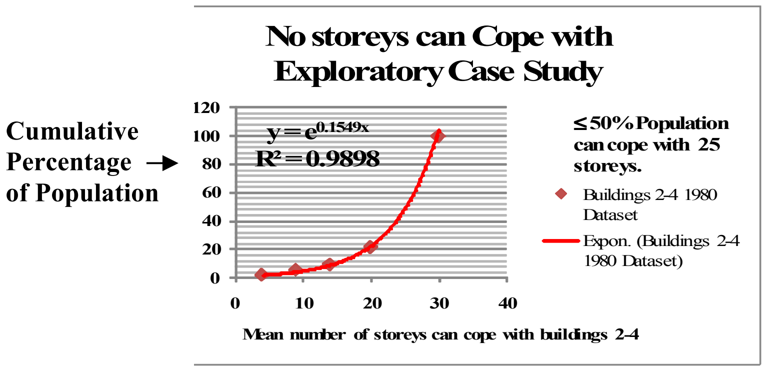


Figure 5-4: Estimated Stair Descent Capability – Exploratory Case Study.

50% of the population as a response from the trial evacuation estimated[147] that they could cope with more than 25 storeys. When this is seen in the context of the results from Part One of the Exploratory Case Study then it could argued that this would be based on the 29.8% of the aggregated sample for that study being committed to fitness.

Table 5-3 shows that dizziness or vertigo is not accounted for significantly by the number of storeys or number of turns or changes in direction. 32.3% of the respondents in Building 4 a clear 11% increase above the rest of the buildings. This is similar to the response for fatigue.

The exemplar buildings are representative as they fall within the overall response pattern over the eight buildings for most of the health conditions/ functional limitations as shown in Table 5-4 below.

building id/condition	extreme	very much	moderate	slight	not at all	no storeys	no cases
3 - knees	2	3.4	4.8	23.8	66	33	147
3 - chest	0	0	1.4	6.8	91.8	33	147
3 - fatigue	0	0	2.7	16.2	81.1	33	148
3 - balance	0	0	2.7	16.2	81.1	33	148
7 - knees	0	3.1	0	10.4	86.5	20	96
7 - chest	1	0	1	2.1	95.8	20	96
7 - fatigue	1	1	1	3.1	93.8	20	96
7 - balance	1	1	1	3.1	93.8	20	96

Table 5-4: Intrinsic functional limitations (Summary for Buildings 3 and 7).

The above table shows that the majority of respondents in each of the exemplar buildings did not really experience any level of discomfort varying from 66% for knees to 91.8% for the chest for building three and 86.5% for the knees to 95.8% for the chest for building seven. The pattern is similar for the two buildings with the number of storeys making most of the impact on knees (R^2 =.73 as opposed to .50-.60 for the others; $p<0.01$). A visual presentation of the above may be found in Appendix A5.

[147] The estimate was a direct response to a set question in the survey questionnaire handed out after each trial evacuation and may be found in Appendix A3. The same question was also included in all the questionnaires forming part of the same survey after the 2008-2010 case study.

5.4.9 Fatigue and distance

As stated in Chapter 1 the aim of this thesis is concerned with the performance of office workers descending multiple flights of stairs in trial evacuations. One of the crucial questions asked in the Exploratory case study questionnaire (see Appendix A3) was how many storeys the respondent could cope with without a rest. They were also asked other questions from which their level of fitness could be established. Fitness here includes “aerobic” fitness and therefore the actual dynamic capacity of an individual to cope with a physical challenge (Ottevare et al, 2011) such as going down multiple flights of stairs. The Exploratory case study uses a non-validated self reporting method. The Canadian Study (Beck, 1977) shows the attitude of occupants to fitness at that time. A preliminary linear regression analysis in where the level of estimated fatigue is used to predict the variation in the number of storeys an occupant traversed in a trial evacuation from the 1980 Dataset shows an R^2 value of 0.5956 ($p<.05$). Given that the International Physical Activity Questionnaire which can measure the actual dynamic capacity had not been developed at the time when the original survey was designed and administered the author proposed that traversed distance could be loosely equated with estimated distance using the data from Buildings 2-4 which in turn can be regressed against the distance that they traversed during the trial evacuation.

The above analysis could also be challenged by Galea et al (2008) where they show that an analysis of the WTC 9/11 incident data did not show a significant relationship between fatigue and the distance traversed. They (Galea et al, 2008) did accept that the relationship may have been masked by the impact of density. Other studies do show a relationship (Ayis, 2007; Peacock et al, 2009; and Fritz, 2009) so that it could be argued that there would be some sort of relationship where density was not a critical issue. This finding is also similar to that presented in Chapter 7 for Building M5 where the survey respondents reported severe crowding.

5.4.10 Conclusion for Part Two: Exploratory Case Study.

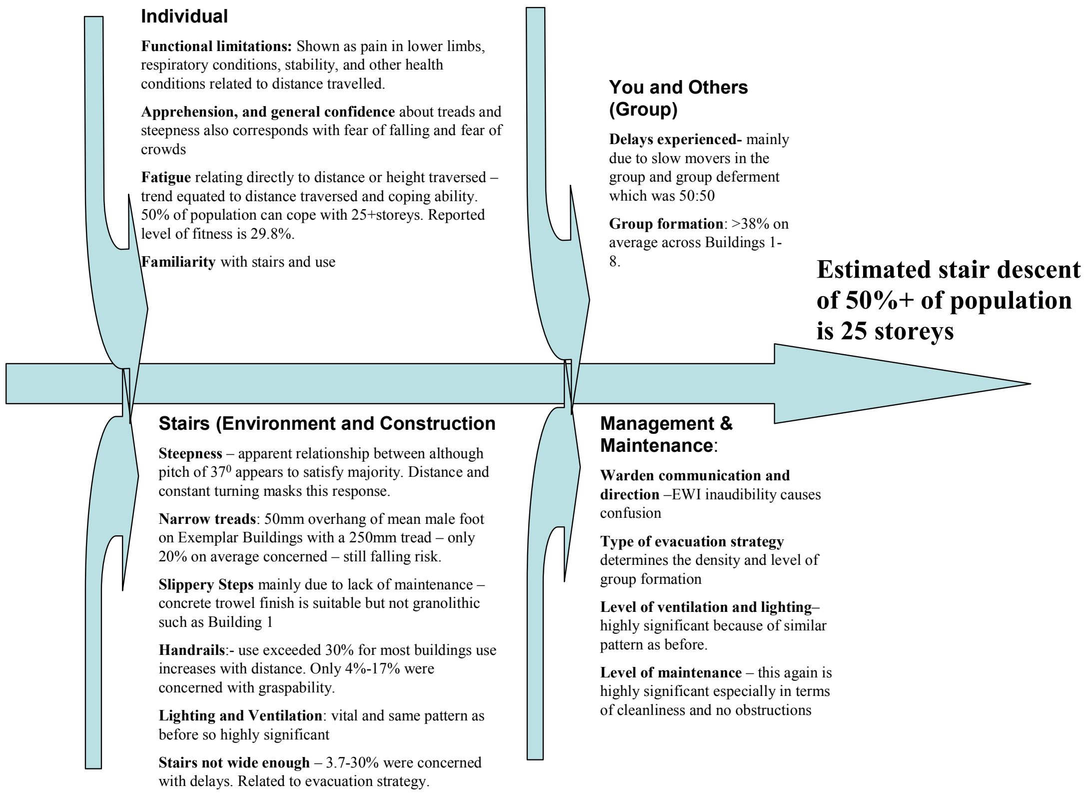


Figure 5-5: Summary of Exploratory Case Study Analysis of 1980 Data-set.
*(Estimated stair descent capability or performance was therefore determined by survey)****;***
****=p<.05, **=p<.01 and***= p<.001***

Figure 5-5 summarises “extrinsic factors 1-6” and “intrinsic factors 1-3” under the generic core consistencies of “the individual”, “stairs (environment and construction)”, “ you and others (group)” and “management and maintenance” each of which constitute a “branch” feeding into the “spine” which determines the outcome which is “individual performance”. Each category noted against each “branch” comprises the pattern and synopsis of the results.

The comparison between the results for Parts and Part Two of the Exploratory Case Study will be discussed in the next section.

5.5 Discussion of Parts One and Two of the Exploratory Case Study Results.

The results are summarised in Figure 5-6 will be discussed "branch by branch" as the context of an occupant's estimated capability as it existed in the 1980's.

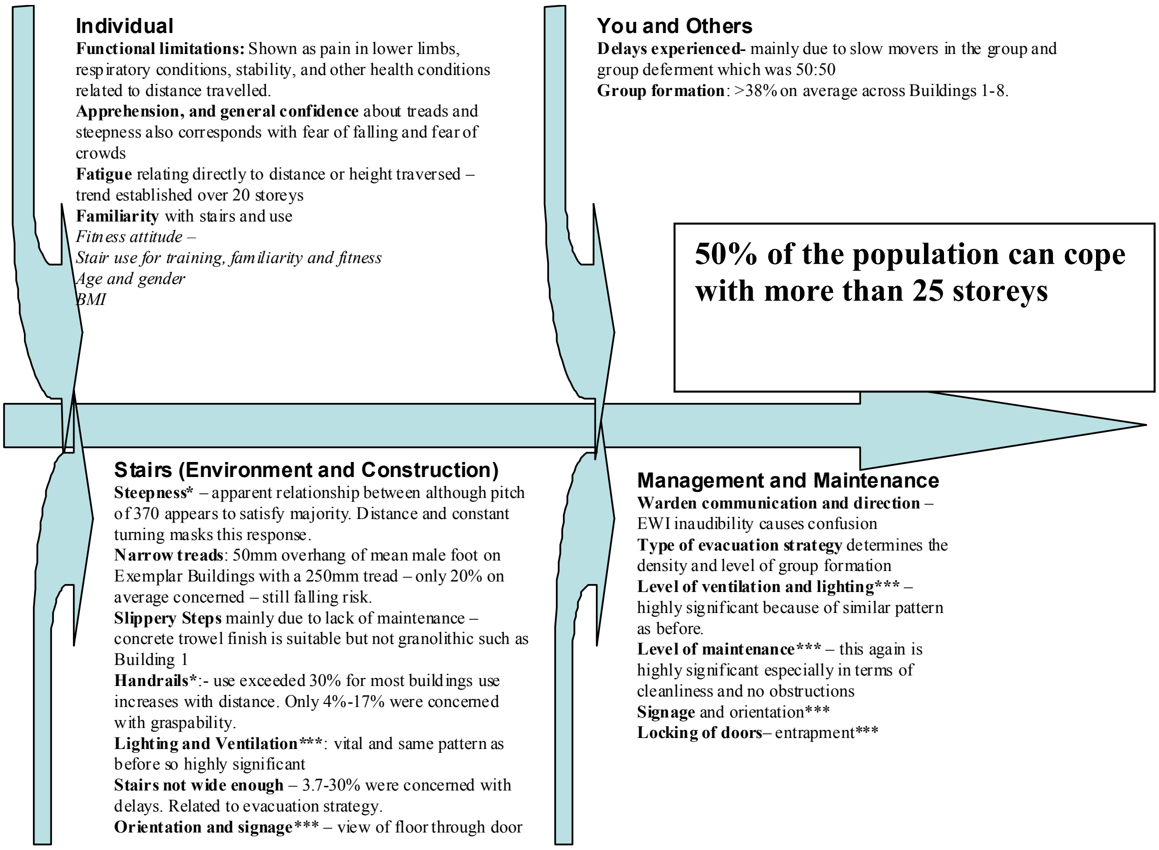


Figure 5-6: Summary of Parts 1 and 2 of the Exploratory Case Study in a Combined Ishikawa Chart.

5.5.1 The Individual Occupant

The population profile for the Canadian Study (Beck 1977) and the 1980 Study are very similar (Rowland, 1991) in terms of the make up of those over the age of 40 years representing the mature office workers (19.2%). This is much less than those noted in later surveys (Dixon, 2003) where the mean working age in the next decade will be > 40 years. The population has therefore aged but whether this is reflected in their ability to go down multiple flights of stairs or not given that functional limitations increase above this age (Ayis, 2007; Domus and Krampe, 2010; Lauretani et al, 2003 and He and Baker, 2004) will be explored further in Chapter 7.

The two seminal studies at the time (Archea et al, 1979 and Templer 1992) showed the following functional limitations were considered to influence missteps:

- Dizziness
- Hypertension
- Impaired hearing

They did acknowledge that more research was being carried out by epidemiologists so that change was expected. Templer (1992) did realise that functional limitations such as obesity and sarcopenia[148] could contribute to loss of balance as confirmed later (Stel et al, 2003 and Fjelstad et al, 2008). It is interesting to note that the results in Part Two show an increase in knee pain for the distance traversed for Buildings 3 (33 storeys) and 4 (45 storeys). Knees were followed by balance as the highest frequency of response.

Table 5-5 below contains comments on the Individual Occupant or Intrinsic Group of Factors summarised in Figure 5-6 above. Interesting points of note are:

- Age and Gender (Templer (1992) shows no correlation between age and rate of falls. Differences in terms of gender were found but are not later agreed with by Peacock et al (2009).
- Fatigue and distance traversed – trends show up in the Part Two of the Exploratory Case Study that need to be investigated further for the exemplar buildings especially with the impact of "density" where

[148] Sarcopenia is the loss of muscle mass with age due to physical inactivity

velocity reduces as density increases (Fruin, 1987). Galea et al (2008) show that density may mask fatigue which does relate directly to descent speed and distance (Spearpoint and MacLennan, 2012). The exploratory case study exemplar buildings do not provide sufficient evidence for this other than relying on observers' comments.

- Balance (dizziness and vertigo) and strength – some trends do show up which are related to distance traversed which does relate to strength. It relates to vestibular disorders but can be closely related to other neurological disorders as well (Samy and Hamid (2010). There is also a connection between anxiety and balance disorders (Yardley and Redfern, 2001) so that fear of falling can be a co-morbidity issue. Steep stairs and the constant downward spiral of stair descent can also trigger dizziness especially with the obese (Teasdale et al, 2007) so that the 2008-2010 Case Study correlations will need to explore the significance of these relationships.
- Apprehension about footing and stance – no measurements made on size of feet but mention is made of another study by MacLennan et al (2011) concerning older people and outdoor steps where there was a relationship established and the mean foot length established as being 300mm. The mean age of the sample was 66 years so that the mean age of the same sample in 1983 would have been 38 years. It is not known whether the apprehension they highlighted would have been the same in 1983. Apprehension about footing and stance may increase with distance and fatigue as shown in the results for Building 4 (Stel et al, 2003 and Verghese et al, 2008).
- Musculo-skeletal aspects of knees and how this relates to the lower limbs especially - results show a direct relationship with distance which is again supported by other studies especially with steepness (Johnson and Pauls, 2011 and Moody, 2000). This will be discussed further in Chapter 7.

- Management implications where there is poor maintenance of lighting and ventilation within the stair enclosure together with lack of cleanliness and deterioration of surfaces (Beck, 1977; Startzell et al, 2000; Templer 1982 and Archea et al, 1979). The results from the exemplar buildings agree with these external findings. One of the most interesting findings from the Exploratory Case Study was that over 40% of the occupants in the Canadian Study did not use the stairs because of management constraints and also the fear of being locked in the stairwell[149] without a known way out (NCBI, 2012) that can induce dizziness and nausea.

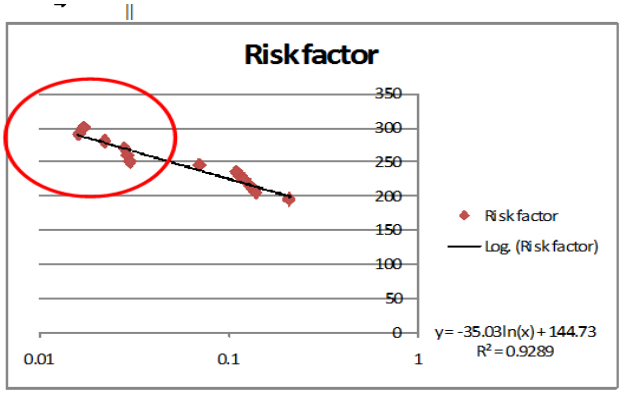
The above therefore summarises the context of the intrinsic factors which determined that only 50% of the population can cope with more than 25 storeys. Pauls et al (2007) said that this would change due to increased physical inactivity. This measure was challenged by the Delphi Group as discussed in Chapter 6 seeing that obesity and the like would be based on self reported measures. Booth et al (2002) showed that BMI was a relatively reliable measure of physical fitness. Also the fact that functional limitations increase with age (Ayis, 2007; Domus and Krampe, 2010; Lauretani et al, 2003 and He and Baker, 2004) coupled with an associated increase in obesity (Al- Abdulwahab, 1999), and that fatigue is associated directly with these limitations, the perception could be correlated with a variable representing or summarising the above could be used to predict the estimated distance the occupant could cope with. This is achievable via factor analysis and will be explored in Chapter 7.

[149] i.e. entry and exit fire doors being locked or even the belief that the doors may be locked.

Individual / Intrinsic Issue or Characteristic	Part One Exploratory Case Study (Content Analysis of Beck (1977).	Part Two Exploratory Case Study (1980 Data-set)	Comments
Age and Gender	Age **(19.2%) measured via estimation.** Gender **was approximately 50:50.**	**Approximately 20%+ when based on statistics (Rowland, 1991). Gender was approximately: 45% male 55% female Only one reported fall requiring treatment in building four was a woman.**	**Justifies the suitability of the studies for comparison in terms of the population and functional limitation profile. Archea et al (1979) and Templer do suggest some differences based on gender. Templer (1992) did claim that age does correlate with the rate of falls and that women tended to fall more than men. Footwear plays a role in this regard.**
Functional Limitations	Functional limitations **presented as general physical impairments, reduced vision, vertigo and dizziness, and fear of falling. Fitness attitude in items that exclude people from using stairs normally ties in with fitness attitude.**	**Functional limitations presented as musculo skeletal to knees, cardio-respiratory – chest, vertigo and dizziness, fatigue and number of storeys can cope with.**	**Refer to opening paragraphs in this section (Templer, 1992, p. 14) where only correlation and falls on stairs is for individuals with cardio-vascular problems. Some very strong relationships show up for knees, fatigue and distance traversed in 1980 Study which does not line up with the seminal studies. Trend shows up for buildings in excess of 20 storeys. A certain agreement between fitness attitude and fatigue if the similarity can be shown – see section A6.2.3.3.**
Familiarity with location of stairs	Familiarity with location of stairs – **no mention other than >40% of population do not use stairs.**	**Familiarity with location of stairs promoted by direction provided by wardens.**	**Direct comparison not really possible but impact of warden direction is still relevant given cases such as Cook County Incident (Proulx and Reid, 2006). See previous comments re prior experience, expectations and training on the approach of an individual going down the stairs.**
Apprehension / Degree of Confidence/ Fear of falling	Apprehension (Confidence/ fear of falling) **about width of treads and slope of stairs – not really reported – treads were 250mm wide as per 1980 Study**	**Apprehension about width of treads – significant percentage were concerned but not as many as expected given that at that time mean toe overhang for males was 50mm.**	**Slope basically the same at 36-37^{0} – significant for small percentage where pattern agreed with that for functional limitations. Apprehension levels did compare with fear of falling but larger % age in 1980 Study although majority still > 34% on average. Both seminal studies do comment on this.**

Table 5-5: Comparison of Parts 1 and 2 of the Exploratory Case Study for the Individual Occupant – Intrinsic.

5.5.2 Stairs (Environment and Construction



Risk factor (%age)	Tread or going size
0.017	300
0.016	290
0.022	280
0.028	270
0.029	260
0.03	250
0.07	245
0.11	235
0.12	225
0.13	215
0.14	205
0.21	195

Figure 5-7: Risk of falling and going width (Adapted from Johnson and Pauls (2011) based on data from Wright and Roys 2008; Equation y=-35.03ln(x) +144.73 with R^2=0.88 and p<.001).

The exemplar buildings 3 and 7 show that only 5-11.5% of respondents were concerned about their safety. There may be a conflict with the degrees of risk projected from the UK Data Base analysed by Wright and Roys (2008) by the author using the interpretation of Johnson and Pauls (2011) but for treads >250mm in width the risk diminishes rapidly (see Figure 5-7). This supports the low response as a large percentage of the sample in the above study (Wright and Roys, 2008) comprised domestic stairs with treads much less than 250mm. A comparison with a potential shoe size for a UK sample related to the time of the 1980 Study (MacLennan, 2011) shows that the drop off in the percentage of risk associated for goings ≥ 250mm can be expected as the mean length of the sample's foot was 300mm.

The steepness of the stairs does appear to be significant and this needs to be analysed further in the 2008-2010 Study where an extensive factor analysis of the aggregated sample of Buildings M1-M6 supports the concern and possibly the analysis in Figure 5-7 above.

As before Parts 1 and 2 are compared for this group of extrinsic factors in a self-explanatory table (Table 5-6). The latter shows that the two factors that were not included were:

- Uniformity of steps / stairs
- Width of stairs in terms of user reach

The uniformity of steps is extremely important and is taken as a major initiator of falls (Templer, 1992 and Archea et al, 1979). Uniformity here is dimensional regularity. The irregularity is important in terms of the location of the actual step in the flight. According to both Templer (1992) and Archea et al (1979) as discussed in Chapter 2 the highest risk location is the first three steps in each flight. This factor is relevant for high rise office building stairs but its contribution to falls is less clear cut. The dog leg stairs in the exemplar buildings, three and seven, have landings at each storey with intermediate landings in between. The highest risk would therefore appear to be at the point of entry, and at the points where the occupant or individual change their gait. The initial foot movement pattern according to Archea et al (1979, p.17) is "toe-down to partially horizontal to toe-down to horizontal". This variation is due to the uncertainty associated with foot placement. Once the occupant becomes familiar with the stairs they develop the resources and use them automatically. This applies even when they alter their gait on each landing because the turning behaviour and gait changing become part of a cycle using Horak's construct (2006) and the flow chart referred to by Archea et al (1979). It is argued that although the uncertainty would decrease as the occupant "learns" by descending through a number of storeys they may also loose "focus" due the increased familiarity, distractions (Horak, 2006) and possibly loss of strength (Stel et al, 2003). Any sudden dimensional irregularity at the head of each flight would pose a similar risk to that experienced at the entry point and slightly less in mid-flight. Short flights might still pose risks but this information was not addressed in the Exploratory Case Study.

It should also be noted here that both seminal studies referred to in this section (Templer, 1992 and Archea et al, 1979) and also in Chapter 2 showed that the number of turns also contributed significantly to accidents. Results from the 1980 Data-set are not available for this factor although a fall was attributed to this factor for building number four where a female occupant of 40+ years was attended to by paramedics after the trial evacuation.

The minimum "clear" width of the stairs was addressed in the Codes[150] at the time and was 1020mm. This represented two people walking side by side occupying a channel 510mm wide. This did not conform to the standard body ellipse proposed by Fruin (1987). Archea et al, (1979, 20)) view the width based on ease of movement and access to handrails for support. They placed any width above 1530mm (5'1") as high risk. It is interesting to note now that research (Peacock et al, 2009) recommending increasing the minimum width to allow for the contra-flow of fire-fighters is in conflict. The Codes[150] at that time required an additional handrail once the width exceeded 1525mm which means that it would have qualified as a low risk stair. 20.7% of respondents from the Part Two Exploratory Case Study agreed on average that the stairs were not wide enough and this percentage was higher for buildings one, two, four, and seven where there was some counter-flow due to fire-fighters. This agrees with later findings of Peacock et al (2009). Respondents most likely thought that the stairs were not wide enough because they may have not been able to overtake slower movers if one examines the results in where 49.6% of them experienced slight to extreme delays due to slow movers and perhaps merging as later suggested and demonstrated by Boyce et al (2009). "Delays due to slow movers" was also confirmed via site observation by observers moving within the groups.

[150] Buildings one to eight at the time of the 1980 Study were governed by Part 24 of the State Codes which were all based on the former Australian Model Uniform Building Code under the supervision of the Interstate Standing Committee on Uniform Building Regulations (ISCUBR)

Element	Part One Exploratory Case Study (Content Analysis of Beck (1977).	Part Two Exploratory Case Study (1980 Data-set)	Comments
Treads	Tread width not mentioned as being significant by users.	Only average of 20% with similar pattern across all eight buildings showed some apprehension.	*MacLennan (2011) shows that mean male foot of 1977 would have resulted in a 50mm overhang and affected front on user stance. Later studies by Roys (2006) confirm this and link it with a major cause of falls (extrinsic factor. Archea et al (1979, p.20) classifies 250mm as high risk. Archea et al (1979) also mention step legibility (marking of nosing)*
Pitch*	Pitch or slope of stairs seen as relatively significant factor. Actual pitch is 36^0-37^0	Steep stairs were seen as a minor factor but those who thought that 37^0 were too severe averaged just 6.5% over the eight buildings in a similar pattern.	*Rowland (1991) showed that 6.3% of the Australian population had some sort of functional limitation during that decade. This would appear to be of the same magnitude as the 1980 Study. Archea et al (1979) also mention the slope in terms of riser height.*
Handrail (location, height and graspability)*	Handrail height of 1067mm was seen as acceptable. Graspability not mentioned as a factor.	Handrail was used by an average of 32% across the eight buildings and only 8.8% found them awkward to use.	*It would appear that handrails were significant at the time in terms of their use and both studies do appear to agree on this. This is supported by Archea et al (1979) who also provided expert opinion on the Canadian Study. Archea et al, (1979) did mention graspability and mention handrails as support mechanisms (p.9).*
Surface Condition***	The degree of slip was significant and was mainly due to level of maintenance and was seen as significant.	Only an average of 6% of all respondents spread in a similar pattern across eight buildings so not taken as significant by users	*Slip resistance was seen at the time by Templer (1992) and Archea et al (1979) to be extremely important and data actually showed that irregular and slippery surfaces do contribute to missteps and falls.*
Lighting/ legibility***	This was seen as being of extreme significance in terms of visibility, foot placement and orientation.	Although an average of 6.3% across all buildings it was seen as being significant because of the low number of respondents who adopted a neutral position and the similar response to the Canadian Study.	*Visibility of the stairs and handrails, the legibility of each step along with the visibility of the entire environment assists the user with proprioceptive feedback and positioning their limbs in space e.g. foot placement as well as orientation. This was supported at the time by Templer (1992) and Archea et al (1979). Archea refers to poor lighting causing falls (p.9. Nosing definition is still important as mentioned under "treads".*
Ease of access***	Doors were locked in some of the buildings. This was the reason given by respondents for not using the stairs.	No similar comments made in 1980 Study although being able to see what was happening on each level was extremely important to the majority of people (>70%).	*Mentioned in Archea et al (1979) where it answered the problem by providing signage as the fact. Should also provide points where access is available. This still does not answer the restriction that locked doors provide to everyday use.*
Ventilation***	This was seen as being extremely significant by respondents.	Averaged 11.8% across all eight buildings and given the large percentages who were satisfied (57.8%) it would appear that ventilation would be a significant factor	*From the distribution of the responses it is reasonable to assume that significance could be generalised between the Studies given the similarity of the patterns (Yin, 2009).*
Signage and Orientation***	Being able to view the floor and know what level they were on was highly significant	Not really measured in Part Two but stair location was important so that generalisation can be made.	*Templer (1992) supports signage and this would help to alleviate the feeling of being "locked in" and its connection with agoraphobia.*

Table 5-6: Comparison of Parts 1 and 2 of the Exploratory Case Study for Stairs (Environment and Construction Group – Extrinsic.

5.5.3 You and Others (Group) – Extrinsic

Templer 1992) comments on this core consistency in terms of spatial behaviour:

"*If, however, a group of two or more arrive at the stair simultaneously, all directional codes are set aside, and they occupy the stair as they desire"*[151] ***(****Templer, 1992, p.103****)***

This occupation of space is due to the interaction of the group and is supported by the findings of the Exploratory Case Study and also by a recent study on the use of outdoor steps (MacLennan et al, 2011). The latter also shows a strong correlation between this interaction and a decrease in descent speed.

The research group behind the 1980 Data-set did recognise group formation and location as a relevant issue. Pauls (1977) and Jones and Hewitt, (1985).also found that the group formation was maintained for the entire journey down the stairs. This finding could also be challenged via a content analysis of survivor's recollections of the WTC 9/11 incident as presented in Dwyer and Flynn (2004) and Chapter 6. Further analysis of the exemplar buildings three and seven shows that group formation on the floor was substantial (60.6%) and that this was maintained in the stairwell (87.3%).

Delays were generated by the above behaviours due to slower movers and merging (deferment behaviour). This behaviour can also be affected by evacuation procedures where "wardens" drive the merging patterns. Deferment or merging patterns may therefore vary and this is supported by other later studies (Boyce et al, 2009). The impact of the slow mover within a group can also hold up the groups behind known as "platooning" (Templer, 1992). An experiment carried out by Knowles et al (1976) showed that individuals behind a

[151] The 'platoon' or the act of 'platooning.'

group will tend not to try and penetrate the group's boundaries. Lindskold et al (1976) further supported this behaviour. This could challenge the notion of solving the problem of the "impassable" group with the provision of a wider stair as suggested by Pauls et al (2007). Blair (2010) reported that the data contained in another seminal study (Peacock et al, 2009) which recommended the widening of stairs was extremely "noisy" in terms of behavioural factors and other issues so that overtaking may not have been extensively explored. Group permeability (20%) is minimal using a standard body ellipse of 600mm (Rouphail, 1998). Even with a maximum width based on the reachability of handrails of 1500mm there is no guarantee that this would alter as the group will occupy the entire space (Templer, 1992). The Content Analysis of the WTC 9/11 incident (Dwyer and Flynn, 2004) appears to contradict this as there were many examples of members within a group providing space for contra-flow and overtaking (altruistic behaviour also confirmed by Fahy and Proulx, 2005).

The relevance of the group shown by the Exploratory Case Study is the risk associated with a falling incident involving a group member where the others may stop to help. If the group member is morbidly obese or unconscious so that they are a "dead weight" then the delay will comprise the time taken to remove the person to a place of refuge where they can be further assisted or the associated descent speed assisting that person down the remaining flights of stairs (Adam and Galea, 2010). Other studies show that groups can be formed where the means of helping the member requiring assistance has already been organised (Zmud, 2007) and that delays can be kept to a minimum (Adams and Galea, 2010).

The value of groups can therefore be utilised in terms of assisting others if management is involved (Dwyer and Flynn, 2004) but this does not mean that the risk to the group is completely removed. Delays, due to slow movers helping others, needs to explored further and reference should be made to the Content Analysis of NY Times Blog (Parker-Pope, 2008) in Chapter 6.

5.5.4 Management and Maintenance – Extrinsic

Jones and Hewitt (1985) mention about leadership and group formation in building evacuations and how these can be influenced by Management. Part one of the Exploratory Case Study showed up the relevance of maintenance and the state of the stair environment due to ventilation and lighting. The same study also shows the high significance of a clean stairwell. Archea et al (1979) agrees with the importance of maintenance.

The use of stairs results in learned behaviour which can be applied from one stair environment to another (Archea et al, 1979). When an individual descends some stairs for the first time they bring this learning with them. This may result in missteps and/or falls. Regular trial evacuations and the encouraged use of stairs by management can mitigate these problems as the users will be familiar with the stairs. Familiarity with stair use where the “training” is safety focussed could provide an interesting benefit for all (Clemson et al, 2004 and Eves et al, 2008).

Management commitment also relates to the formation of groups so that if this is done efficiently then “assisted evacuation,” utilising the appropriate devices and techniques (Adams and Galea, 2010 and Zmud, 2010), can be beneficial and safe. Management commitment also means appropriate maintenance of the stairs and the environment. Lack of maintenance is a moderately significant problems ($p<.05$) so that this aspect needs to be explored further in the 2008-2010 Case Study.

The exemplar buildings three and seven, as shown in Section 5.4 represent a direct comparison between two different styles of management. Building Three practised what they preached and Building Seven did not. This is an ideal mix for further comparison.

5.6 Summary and Conclusion

The results and discussion for the Exploratory Case Study demonstrate that:

- The aim of the PhD Case Study is substantiated for further study and validation in the 2008-2010 Case Study for exemplar buildings three and seven.
- The selection of the branches of the Ishikawa Chart Model by the United Kingdom Delphi Sub Group representing the Individual (intrinsic factors and characteristics) and the extrinsic factors of " stair design, construction and environment", "management and maintenance", and "groups – you and others" encapsulate all the factors found in the results in this Chapter as those raised in the seminal reference studies (Archea et al, 1979 and Templer, 1992).
- Functional limitations especially musculo skeletal knee pain, fear of falling or apprehension, balance, fatigue/ strength, were significant. Shields et al, (2009) showed in their WTC9/11 Incident Study of evacuees with self designated mobility impairments that the latter did constrain their descent rates to a certain degree but these still compared reasonably well with other studies. Shields et al (2009) go on to warn about the impact of density and delays where the participants would have stopped at various points so that the true movement speeds could be challenged.
- Groups did form and were significant in delays due to merging and "platooning" caused by slower movers and the impact of group space in terms of the intrusion of other occupants following behind.

Groups were also found to be significant in deferment behaviour via additional studies (Knowles et al, 1976).

- Stair design and construction did show some concern with narrow treads. Discussion also demonstrates a large number of respondents who appeared not to be concerned with safety in that they had no opinion concerning the treads. Further studies of mean shoe size of males (MacLennan, 2011) confirmed that treads less than 300mm in width are high risk (Archea et al, 1979). Steepness also featured to a certain extent via triangulation between the pitch of the stairs (35^0 to 37^0) when compared with occupant responses. Other factors of stair visibility, lighting, ventilation, slip resistance, handrail characteristics, were found to be quite significant. Uniformity did not appear in the responses but were added because of results from other Canadian Evacuation Studies (Pauls, 1977).

- Management and maintenance were significant in the forming of groups, potential group behaviour (Jones and Hewitt, 1985), familiarity of stair users with the "evacuation stairs", level of fitness and fitness attitude, level of lighting and ventilation, signage, cleanliness, slip resistance, and evacuation strategy chosen.

Two exemplar buildings[152] that are representative of the eight being buildings three and seven will be included as part of the 2008-2010 Case Study and analysed in Chapter 7 in order to complete the longitudinal nature of the PhD Study.

The "heads of consideration" for the 2008-2010 Case Study are set out in Chapter 6 and comprise the results of the considerations of an International Delphi Group, a BMI Benchmark Group and two specialist Focus Groups

[152] Buildings 3 and 7

comprising those with a BMI in excess of 30 and those with an age in excess of 45 years. The procedures used for each set of Groups are described in Chapter 3. The findings of the Exploratory Case Study will be reviewed together with those from Chapter 6 in Chapter 7

Chapter 6: Results and outcomes for the 2008-2010 Case Study Explanatory Studies (Content Analysis, Delphi and Focus Groups)

6.1 Introduction:

Undertaking the 2008-2010 case study was made feasible by the findings of Chapter 5. The findings from the 2008-2010 Case Study are “framed” in Chapter 6 by the advice of an International Delphi Group and the considerations and measured intrinsic factors of three focus groups[153].

The structure of Chapter 6 is explained in Figure 6-1. The 2008-2010 case study was designed as a flexible process to allow for changes to be made to data collection instruments resulting from the needs of the research procedure. This is explained in Chapter 3.

The Exploratory case study provided the contextual issues that impacted on the performance of the individual going down multiple flights of stairs in trial evacuations. The original data was reclassified into the classifications determined by the Delphi Group providing expert input for the 2008-2010 case study. The findings therefore were taken to represent the level of performance in the 1980’s and could therefore be generalised with the outcome of the Canadian Studies by Pauls (1974). As mentioned in Chapter 2 Pauls, Fruin and Zupan (2007) claimed that the descent ability of the individual would have diminished due to the lack of physical activity. The Exploratory case study therefore provided the foundation for a current study and in doing so to confirm or otherwise the claims made by Pauls, Fruin and Zupan (2007).

Concurrent with the 2008-2010 case study of trial evacuations from six high rise office buildings selected in accordance with the criteria described in Chapter 4 some additional explanatory studies were carried out comprising a Delphi Group to re classify the extrinsic and intrinsic issues that provided the

[153] i.e. two special user groups and one benchmark group of fit “young” office workers.

context stair descent and focus groups to "construct" the context based on their own experience. There are two additional qualitative studies presented being the content analysis (Fahy and Proulx, 2005) of documents from the media connected to and arising from the WTC 9/11 incident. These two studies are described in Chapter 3 and also in sections 6.4 of this Chapter.

The Content Analysis procedure used to the data from the focus group and media documents is the same. The coding classification and scheduling system is described and explained in section 6.2 and then applied to the outcome of the focus group sessions in sections 6.6 to 6.8 and comments extracted from the media in sections 6.4 and 6.5. It should be noted that content analysis is used in extracting material from text and notes. Part of the focus group procedure involved survey using the same questionnaires handed out after the trial evacuations and also observations of the focus group members undertaking a mobility test to measure descent speed and performance, This means that mixed methods were used.

The findings are discussed in section 6.9 and summarised under the classification of the context developed by the Delphi Group. The main benefit of this chapter is that the Delphi Group opinion represents a "top down" approach whilst the other "opinions" represent a "bottom up" approach. The result is a more comprehensive set of outcomes that can be used to explain the results from the 2008-2010 case study presented in Chapter 7.

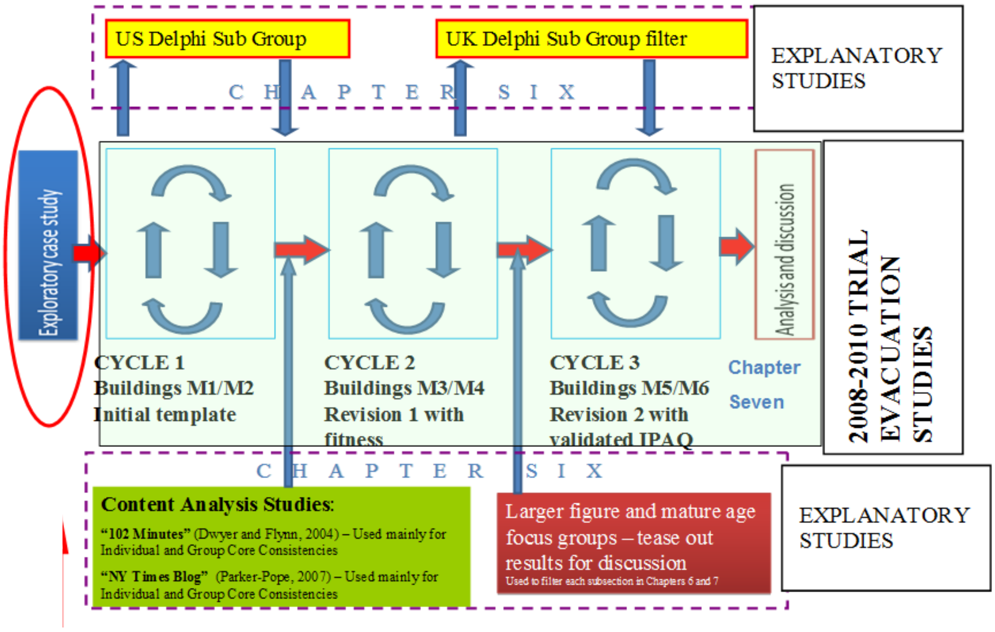


Figure 6-1: Thesis Study and Analysis Process

In Chapter 3 and as shown in Figure 6-1 the process steps described in the above paragraph process were explained. The research method used is mostly qualitative so that a system based on grounded theory and content analysis as described in Chapter 3 was used. As such the interrogation tool used was that based on the literature review in Chapter 2 and the framework developed by the Delphi Group. This is a similar approach to that used by Fahy and Proulx (2005).

6.2 Coding Regime used for Sections 6-4 to 6.7

The outcome from the Delphi Group analysed and presented in the next section uses a framework based on "root cause analysis" (Portwood and Reising, 2007). Content Analysis and grounded theory in line with the intent of Hsieh and Shannon (2005) were used in association with a directed approach to establish core consistencies (Fahy and Proulx, 2005 and Zhang and Wildemuth, 2009).

The method is fully described in Chapter 3 and Appendix A6. The tables that record the comments, their coding and analysis may be found in the Appendix A6. Chapter 6 should therefore be read in conjunction with Appendix A6. The core consistencies are described in Figure 6.2 for reference.

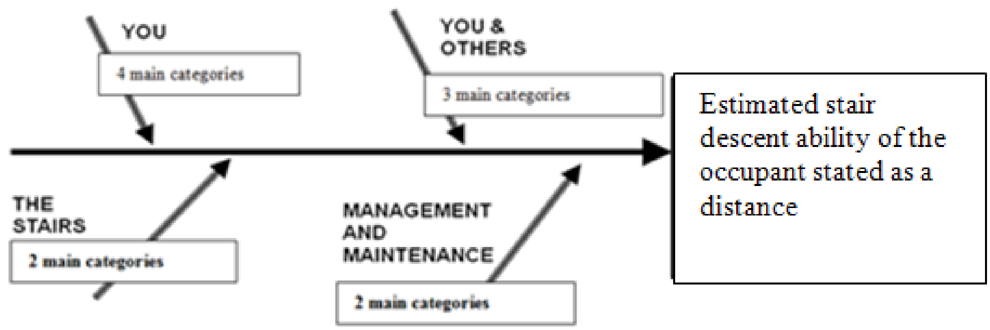


Figure 6-2: Classification Framework of Core Consistencies and Coding Categories

The further coding of the core consistencies may be found in Appendix A6 as this is seen as being part of the data analysis task and therefore is not presented in Chapter 3.

The schedules of the comments and core consistency and the frequencies of their subcategories are presented in Appendix A6 under each appropriate study (Dwyer and Flynn, 2004 and Parker-Pope, 2008).The analysis of these data is presented in Section 6.4 - 6.7.

6.3 Delphi Group Results

The model developed via Delphi Group Consensus is presented as part of the results and also represents the framework used to interact with the research. Although the Exploratory Case Study (Chapter 5) establishes the context of stair use and the possible correlation between estimated occupant stair descent capability with factors making up this context, this relates to the time frame of 1975-1985. There is a need to establish the context of stair use within the current decade. The context of stair use is summarised in Chapter 2 but multiple flight stair descent in high rise buildings is normally seen as being a subset of egress research. In order to provide a platform between users and experts the author utilised the Delphi Group and the associated process (Linstone and Turoff, 2002) in conjunction with the literature review to provide the initial framework. The outcome of the Delphi Group deliberations is presented in the form of completed Ishikawa Charts, with explanations as required, as the consensus of these deliberations.

The Delphi Group was made up of two sub groups as outlined in Chapter 3, one from the United States/Canada and the other from the United Kingdom. A Policy Delphi approach was used (Turoff, 1970). Two meetings were held with the first in the United States. The experts were briefed about the aim and objectives and then each individual given a blank Ishikawa Chart with instructions on how to develop them. The charts were completed by the experts classifying the contextual factors and noting them on the "fins" of the diagram. They were then asked to populate each fin in turn. The completed charts were handed to the author who was the facilitator. The facilitator then exchanged the charts and asked for the experts to review each other's charts. They spent some time on this and agreed that they would not subtract anything from each set of opinions. They advised the facilitator to integrate the opinions. The outcomes from the US Group are shown in Figure 6-3. Consensus did not form part of the proceedings.

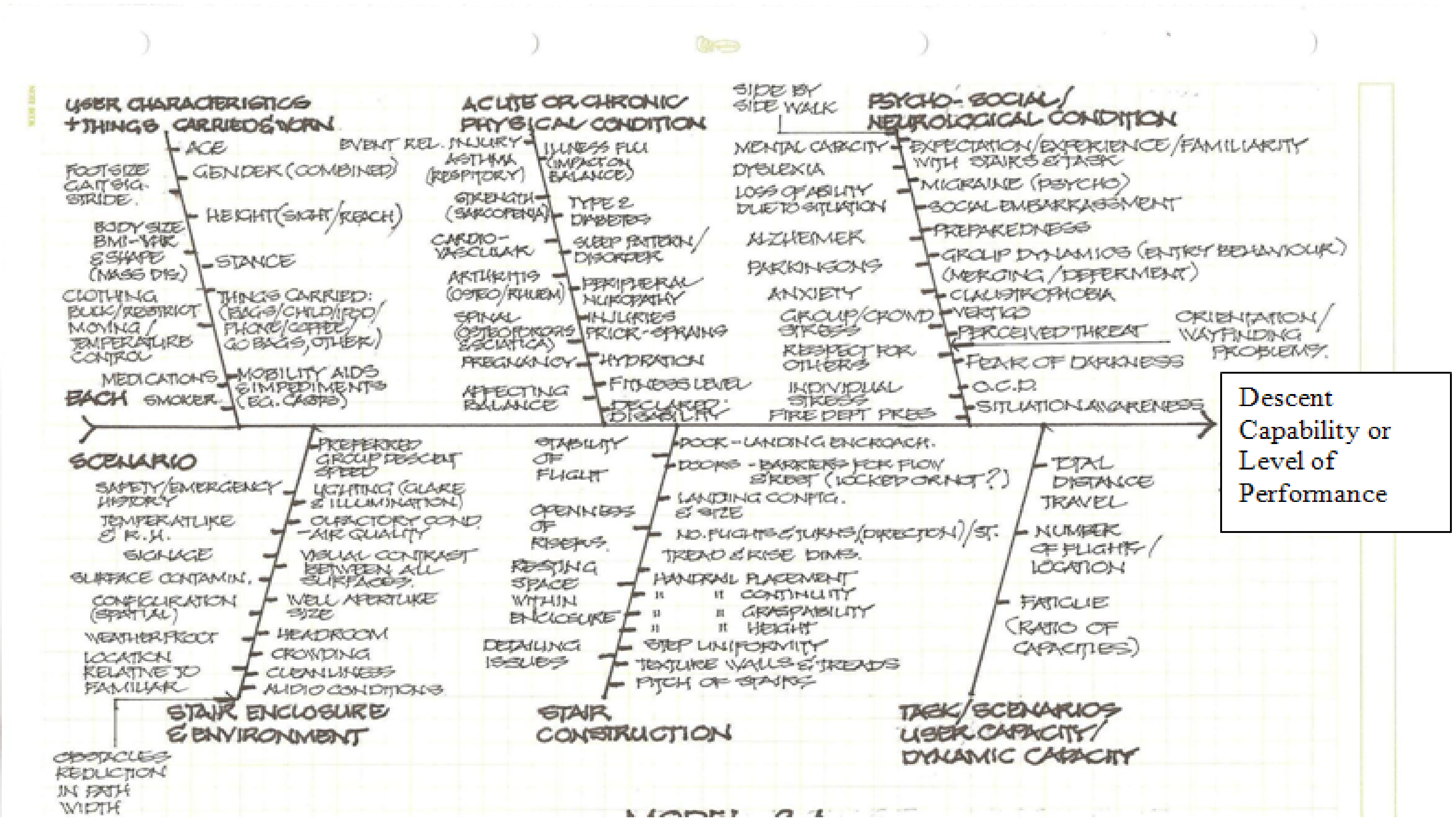


Figure 6-3: US Delphi Sub Group Outcome – “used as aide-de-memoire”

The membership of the two sub groups forming the Delphi Group is presented in Chapter 3. The US Sub Group prepared a model that represented the whole field of stair use, egress and safety that was decidedly "engineering science" based. The UK Sub Group which was more representative of the "health science" school challenged the outcome shown in Figure 6-3 with a general comment of:

The initial outcome is far too involved and complex to provide the framework required. It provides a good "aide-memoire" for detailed analysis."
(UK Subgroup 2008)

The UK Subgroup were each individually provided with their own copy of the integrated US Ishikawa Chart. They were seated around a rectangular some distance one from the other to minimise co-operation. The author again was the facilitator. The group asked further questions about the aim and objectives of the study. Members were then each individually asked for their comments. The initial comments showed that there insufficient allowance for the impact of man agreement and others using the stairs. They also individually commented that there were too many classifications. It needed to be simplified. A fresh chart was prepared and circulated with the new broad classifications as shown in Figure 6-2. They basically agreed with the detail of the US Chart but summarised the factors providing the author with direction in breaking down the elements noted on the branches in the light of the health science and ergonomics based research in the United Kingdom. The final model only contains four main branches which lines up extremely well with the division of the body of research depicted by Templer (1992), Startzell (2000), Reeves et al (2008), Roys (2006) and Pauls (1977, 2007 and 2011). The UK Group advised that the US Chart should be used as an aide-de-memoire.

6.3.1 The US Delphi Sub Group Results

The US Sub Group Meeting was held at the offices of the National Institute of Standards and Technology in Gaithersburg, Maryland. The members of the group each individually completed a blank chart after reaching consensus on the contextual classifications and discussed their findings after completing this task. Overall consensus was reached by the members examining each other's findings and agreeing to subsequent changes. There were no actual changes but rather just additions. The classifications comprised three extrinsic and three intrinsic classifications being:

Intrinsic Groupings:

As seen in Figure 6-3 the intrinsic classifications are:

- User characteristics and things worn. (10 subcategories)
- Acute or chronic physical condition.(14 subcategories)
- Psycho-social or neurological condition.(18 subcategories)

Extrinsic Groupings

As seen in Figure 6-3 the extrinsic classifications are:

- Stair enclosure and environment (10 subcategories)
- Stair construction (14 subcategories)
- Task scenarios (3+ subcategories)

The resultant chart established $64^{\wedge 64}$ possible permutations and combinations. This was considered to be far too complex.

6.3.2 UK Delphi Sub Group

The frequency and organisation of trial evacuations depend on the commitment of the employer and/or the owner of the building to occupational health and safety. This commitment is reflected in the emergency evacuation plan and procedures for the building. Management can therefore have a direct impact on the frequency and procedures followed in trial evacuations and the behaviour expected from the workers or occupants. The UK Subgroup was of the opinion that "Management and Maintenance" could determine the grouping of the occupants, the evacuation sequence and strategy as well as the state and condition of the stairs and the stairwell. These classifications represented the sum total of the extrinsic factors. The intrinsic factor was dealt with via a single classification comprising a number of variables. This followed the desired framework for the design of the questionnaires which needed to resemble the one used in the research project providing the 1980 Data-set as closely as possible.

The branches were then simplified by the group members individually and then settled on by consensus from the US outcome as follows:

- The **Individual** or "You" (9 subcategories that could be expanded)
- The **Group** or "The Individual/You and Others" (5 subcategories expanded below)
- **Stairs and Environment** (Stairs, Design, Construction and Environment) (18 subcategories)
- **Management and Maintenance** (7 subcategories)

The "**Individual**" was intended to group all the intrinsic factors together in terms of age, gender, mass, functional limitations, psycho-social and neurological factors, and abilities/ experience.

The "**Group**" or "**You and Others**" was intended to reflect the impact of group size, composition, cohesion, prior member location and relations, where group formed, formed voluntarily or via management procedure, dynamics, behaviour (altruistic or aggressive), and commitment.

The "**Stairs, Design, Construction and Environment**" should comprise those factors shown to be critical by the research. Roys (2006) was the source for this so that the following factors were included; tread width, uniformity of step geometry, illumination, number, height and graspability of handrails, contrast between surroundings and steps, legibility of steps, slip resistance of steps, and number of steps per flight. Other factors that were included after further consultation were pitch or riser height, contrast of handrails, step edge conspicuity, width of stairwell, distractions, and encroachments.

"**Management and Maintenance**" should comprise the evacuation organisation makeup (central and local). It also should include the legislative context, strategy and planning process (authoritative vs. participative), procedures, organisation and team structure, and frequency of drills. Feedback was also considered to be vital following something similar to the PDSA cycle. Emergency instructions and scenario practice were also mentioned.

The initial consensus reached by the UK Sub Group still contained all the elements listed by the US Sub Group so that overall Group consensus was still maintained. The UK Sub Group classifications were therefore expanded slightly via further consultation with the members being continually cross-referenced with the US "aide-de- memoire".

6.3.3 Discussion of Delphi Group Outcomes

The US Delphi Subgroup outcome shown in Figure 6-3 is in extreme detail and contains the issues raised in the literature (e.g. Archea et al, 1979; Templer et al, 1972; Pauls, 1977, 2007 and 2011; Startzell et al, 2002; Roys, 2006; Scott, 2005; Maki et al, 1983; Aldersen, 2010; Averill et al, 2005 and Peacock et al, 2009) other than those dealing with evacuation management and group issues. The Exploratory Case Study did raise some pertinent issues in this regard as did other research at the time (Pauls, 1977; Beck, 1977; Templer, 1992; and Knowles et al, 1976) especially:

- Level of maintenance especially keeping the stairs clean and free of obstructions. This should be extended to keeping elements such as handrails, nosings and the like secure and generally maintaining the required level of safety**.**

- Level of maintenance of the stair environment such as level of lighting and ventilation.

- Group formation – voluntary (work location or organisation structure based) or as a result of the local or central evacuation procedures. There is also the primary and affiliative group model as pointed out by Shields et al (2009) where those occupants who “self designate” their functional limitations may form smaller groups for trial evacuations and emergencies such as the person with the Evac+ chair in the WTC 9/11 incident (NFPA, 2007 and Zmud, 2007).

- Group dynamics and cohesion which will determine occupied and “owned” territory, relationships with other groups (merging), and type of behaviour.

- Group size especially in relation to stair width and “permeability” of the group in terms of “platooning”**.**

The structuring of the Delphi Group into two sub groups may be seem as being outside the definition of the Delphi technique which as stated in Chapter 3.

6.4 Content Analysis Study 1 – WTC 9/11 incident (Dwyer and Flynn, 2004).[154]

The content of the publication of WTC 9/11 survivor interviews entitled 102 Minutes (Dwyer and Flynn, 2004) was analysed using the same approach as that of a similar study by Fahy and Proulx (2005). The process is described in Section 6.2 of this chapter together with the coding regime, tables of abstracted comments together with their coding into core consistencies and finally tables showing the frequency of subcategories in each core consistency or classification. The outcomes from this content analysis study mainly focus on the interaction between survivors as groups, between groups and wardens and to a certain extent between survivors and stairs.

The outcome of the analysis summarised in Table 6-1which are summaries of the subcategory/ core consistency tables in the Appendix A6 comprised:

- 66 abstractions from the actual document comprising references 102.1 – 102.66 as listed in Appendix A6.\
- 29 of these were coded as "You", 31 as "Group", 21 as "Stairs" and 37 as "Management".

Core Consistency	Number of Codings	Percentage of Total Codings		Percentage of Total Abstractions	
You	29	29/118	25%	29/66	44%
You & Others	31	31/118	26%	31/66	47%
Stairs & Construction	21	21/118	18%	21/66	32%
Management & Maintenance	37	37/118	31%	37/66	56%

Table 6-1: Frequencies of classifications against core consistencies (Dwyer and Flynn, 2004)

The percentage of total abstractions shows that the main core consistency was "Management" followed by "Groups", "You" and "Stairs". "Management"

[154] Refer also to Chapter 3 for full description of Method

comments mainly involved actions of wardens which can be summarised as "altruistic". This type of behaviour was by far the most frequently encountered across three out of the four core consistencies and confirms the findings of Fahy and Proulx (2005). A selected cross section of the comments from Schedules 1-20 in Appendix A6 are shown below:

Comment 102.1

"The immediate challenges these people faced were not geopolitical but intensely local; for instance, to open a jammed door, navigate a flaming hall way, or climb dozens of flight of stairs. Occupants had to care of themselves and those around them........."
Dwyer and Flynn (2004, p.xxi). Covers all four core consistencies.

Comment 102.5

"Grab your bag," Yagos said. "We're going". Next to them, Ann McHugh also rose to leave.....'
Dwyer and Flynn (2004, p24). Applies to the Group core consistency dealing with the formation of a group on the floor in the work area. The workers were work colleagues.

Comment 102.9

"....Many of the people who worked for the bank had been in the building in 1993 so the memory of the calamity ran just beneath the surface......That experience had helped turn emergency preparations into a near religion amongst employees. People learned where the fire stairs were.......One of the banks leaders had sent a memo making their policy clear.....people were the bank's assets....."
Dwyer and Flynn (2004, p29). Past experience resulted in "work culture" of preparedness and a high level of management commitment to the safety of the workers. This is "local management" as opposed to "central management" of the Port Authority The core consistencies involved are "You", "Group" and "Management".

Comment 102.20

"The instruction to the caller from Morgan Stanley was especially important. Morgan Stanley occupied twenty two floors and over 2000 people worked for the company. An executive for the bank, Ed Ciffone, had overseen years of intense evacuation programmes, and one of his deputies, Rick Rescorla, had led the drills with a zeal that seemed near evangelical. ... Now it made sense. Their wardens pulled out megaphones and began to drive the Morgan staff out of the building."
Dwyer and Flynn (2004, p.72). Shows the impact of a committed prepared organisation that also comprised a large tenant. Groups here were most likely a mixture of work colleagues from a particular department or team and those formed in transit to the stairs following the warden's instructions. The core consistencies involved were "Groups" and "Management". If this comment is read in conjunction with comment 102.19 then the potential conflict can be seen with central management directions.

Comment 102.22

"Along the way Foodlum had tired – she had just finished a challenging chemotherapy series for cancer, and was about to start radiation treatment – but her boss...nudged her along" ***Dwyer and Flynn (2004, p.76). Shows individual functional limitation and altruistic behaviour from her boss so that the core consistencies involved are "You" and "Group" as there are two***

people who would have occupied the space on the stairs and who, in other situations may have caused platooning (Templer, 1992).

Comment 102.24

"The single-minded abandon of Michael Sheehan's departure ....should have carried him clear of the tower by 9:02, but several developments managed to slow him down...When he came across a heavy woman...at the 10th floor, Sheehan ....walked down with her ....out of the building." ***Dwyer and Flynn (2004, p.90). Shows that overtaking occurred so that single-minded behaviour may have been initial behaviour but this was replaced by altruistic behaviour with the large woman whom he assisted for 10 floors until they were out of the building. The applicable core consistencies are "You", "Group" and "Stairs". Overtaking did occur so that Sheehan may have moved through group territories. A group was formed in the stairs and on other occasions may have slowed others behind as the group would have occupied the stairs. Rest space would have been appropriate and the stairs were not wide enough as demonstrated by others (Peacock et al, 2009).***

Comment 102.30

"He fixed his gaze on the lip of each step; defined by the glow in the dark stripe and started ....he navigated this line down 1512 steps that led from the 84th floor of the South Tower to the lobby..."

Dwyer and Flynn (2004, p.101). This is an example of the effectiveness of the photo luminescent nosing strips as a way finding tool. It also demonstrates how stair users who are focussed can go down multiple flights of stairs safely. There were others involved as well. Core consistency here is "Stairs".

Comment 102.36

"The line moving along the stairs immediately resumed a fast but steady pace...Soloway took the arm of a woman having a panic attack....Salovich carried the bag of another woman hearing about her two children..."Thirtieth floor'" Salovich called out. "It's all downhill from here." ***Dwyer and Flynn (2004, p.118). This is a classic example of altruistic behaviour and group dynamics where Salovich did not want to compromise the safety of others. His purpose was to help the slow mover and keep the line moving. Core consistencies of "You" and the "Group" apply.***

Comment 102.53

"I've found an exit," he said, and he led them to a door.......She saw a thin man behind her in the stairs........Another colleague, Sankara Velamuri escorted Tembe with his bad knee..." ***Dwyer and Flynn (2004, p.191).Core consistencies of "You" and "Group" apply. It could be argued that "Stairs" could apply as well but the predominant themes are altruistic behaviour and interaction between groups and their members. It shows the value of a "leader" (Jones and Hewitt, 1985) that others are prepared to follow***

Comment 102.65

*"(North Tower) Reese had severe asthma. Everything about the long descent – the heat, the anxiety – tightened the clamp around her throat....her colleague tried soothing assurance, pep talk, pleading... only 5 floors to go and they would be out of the building...**she had to sit.**"*

Dwyer and Flynn (2004, p.228). Shows that respiratory problems are a functional limitation that relates to distance or the number of storeys. Demonstrates altruistic behaviour and the need for a space to rest even if she only had 5 storeys to go down. Core consistencies of "You", "Group" and "Stairs" apply.

The above comments provide a comprehensive cross section of the 66 comments included in Appendix A6. When considered in the context of the Aim and Objectives of the PhD Case Study it provides a valuable insight into the challenge of going down multiple flights of stairs, the natural tendency of group members to help others, the relationship between fitness and distance traversed, the risk to the group of assisting others in terms of physical effort, and the impact of local and central management on stair user/ occupant behaviour.

The abstracted classifications and comments will be analysed and discussed further in a subsequent section where a direct comparison will be made with those from Content Analysis 2.

6.5 Content Analysis Number 2 – NY Times Blog and Comparison with Content Analysis Number 1.

6.5.1 Content Analysis Number 2[155]

The outcomes of the Content Analysis of the NY Times Blog[156] facilitated by Parker-Pope (2008) mainly focus on responses of interested parties on the notion that people may not be fit enough to survive in emergencies or undertake the physical challenges involved (e.g. going down multiple flights of stairs) as well as their attitudes to others who are not fit and those who may be vulnerable in this area.

The nature of the NY Times Blog is described elsewhere in Chapters 3 and 4. Taylor Parker-Pope (2008) facilitated the session and allowed free responses on a set theme of fitness to survive an emergency and community attitudes associated with the issues involved. The responses from the Blog were

[155] Refere to Chapter Three for full description of the method

[156] This blog was influenced by a discussion at the time on obesity and fitness and community tolerance. Parker- Pope tied it surviving emergencies and WTC9/11 was one of the example incidents.

numbered NY1 to NY154 together with the comments made during the session by the facilitator. They are transcribed into tables in Appendix A6 as described in Chapter 3.

An analysis of the outcomes of the frequency coding tables in Appendix A6 show that there were 60 abstractions from Comments NY1-NY154 of which 43 were coded as "You", 41 as "Group", 19 as "Stairs" and 45 as "Management". These details are analysed further in Table 6-2

Core Consistency	Number of Codings	Percentage of Total Codings		Percentage of Total Abstractions	
You	43	43/144	30%	43/60	72%
You & Others	41	41/144	28%	41/60	68%
Stairs & Construction	19	19/144	14%	19/60	32%
Management & Maintenance	41	41/144	28%	41/60	68%

Table 6-2: Frequencies of classifications against core consistencies (NY Times Blog)

The percentage of total abstractions shows that the main core consistency was "You" followed by "Groups" and "Management" together with a relatively small percentage of coding/ classifications against "Stairs" even with the prompting by the facilitator. This may be expected given that comment NY"H" was made after 74% of the NY responses had been received and recorded.

"Management" comments mainly involved suggestions by respondents that wardens should organise trial evacuations so as to avoid blockages that they should become more involved in planning for those who are either unfit or have limiting functional limitations and that trial evacuations are important.

"Group" comments were mixed. The main thrust of the "Group" comments is summarised below:

- Altruistic behaviour would be expected (assisting others) although many comments were the opposite where the person concerned would be prepared to penetrate the group's territory in terms of overtaking.

- Group dynamics where there would be members who would not be prepared to co-operate and would not tolerate slow movers.

- Firm leadership where the good of the group would be seen as paramount.

- Physical implications to and risk for members of the group in assisting others e.g. lifting or supporting morbidly obese persons[157].

- Expectations of aggressive group behaviour.

- Awareness of stress behaviour where slow movers are involved.

- Reference to source of group members such as fellow workers from same department.

- Reference in quite a few comments to the benefit of group "leaders" with prior evacuation experience.

Comments applying to the core consistency "You" were also a mix. There were a few individuals who even with functional limitations had learnt through practice and the use of "willpower" how to use handrails for support and marshal their neural balance control and movement system (Horak, 2006) to be able to go down the stairs. It is here that the provision of rest areas would be important which is also reflected in later comments that stairs

[157] Substantiated also by Heuer et al (2011) and Puhl and Brownell (2001) in terms of community attitudes and stigma.

should be wider. There were some who reflected a level of intolerance. Respondents realised the importance of fitness but were diverted by the internal debate on the possible stigma associated with obesity[157]. Respondents recognised that many moved slowly because they had a fear of falling or lack of confidence. An example is provided of an unfit and obese respondent who could only cope with between 5 and 10 storeys and another who would have not been able to cope with 30 storeys even with rests. Even the greater amount of space on the stairs required by the obese person was mentioned which ties in with later comments on stair width.

Finally the number of comments referring to "Stairs" was almost entirely centred on the width of the stairs. This core consistency only accounts for 14% of the selected responses. It mainly relates to individual contentions that wider stairs would provide space:

- For slow movers to rest.
- Space between group members for others to overtake by passing between so that group territory was not seen as an issue[158].

Unlike the analysis of 102 Minutes (Dwyer and Flynn, 2004) in the previous section the comments have been summarised as a whole without direct references to individual core consistency comments. This is because of the distribution of comments is more uniform.

The details of the comments may be found in Appendix A6.

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[158] Contrary to findings of Knowles et al (1976)

6.5.2 Analysis of Content Studies 1 and 2.

The frequencies of the categories are summarised on Figure 6-4 and Figure 6-5. The detailed allocation of the sub categories may be reviewed in the Appendix A6.

The two selected studies (Dwyer and Flynn, 2004 and Parker-Pope, 2008) are quite different in that one is the recollection of an actual incident so that it is based on fact and perception. The other is the voicing of opinions that reflect community attitudes on fitness and emergencies. The analysis in this section will be comparative so that the findings can be tested against the outcomes of the two Content Analysis Studies to see whether any generalisations can be made in line with case study principles (Yin, 2009).

Inferences can only be drawn from these two studies by further analysis of the categories within the core consistency classifications by means of generalisations made between the two studies in accordance with "case study" practice (Yin, 2009). The above analysis is continued on in this section.

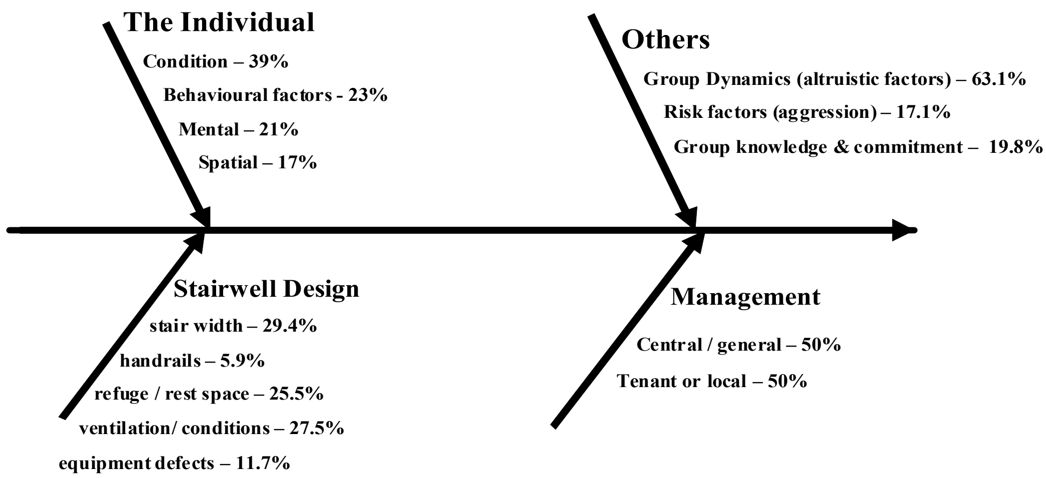


Figure 6-4: Ishikawa Chart Summary – Content Analysis 2 NY Times Blog (Parker-Pope, 2008)

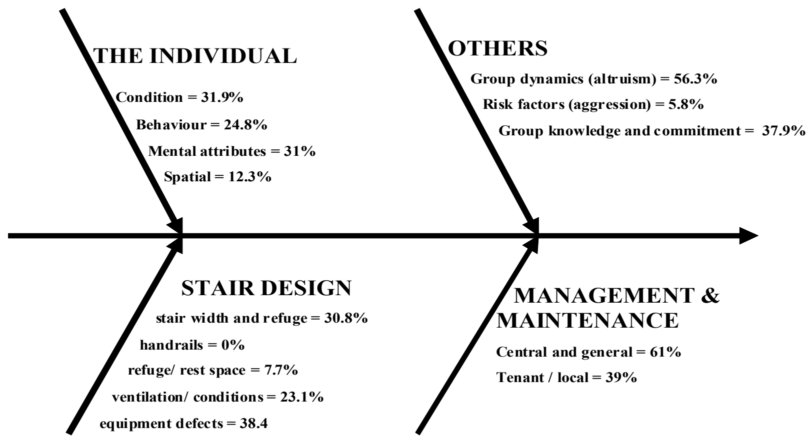


Figure 6-5: Ishikawa Chart Summary – Content Analysis 102 Minutes (Dwyer and Flynn, 2004)

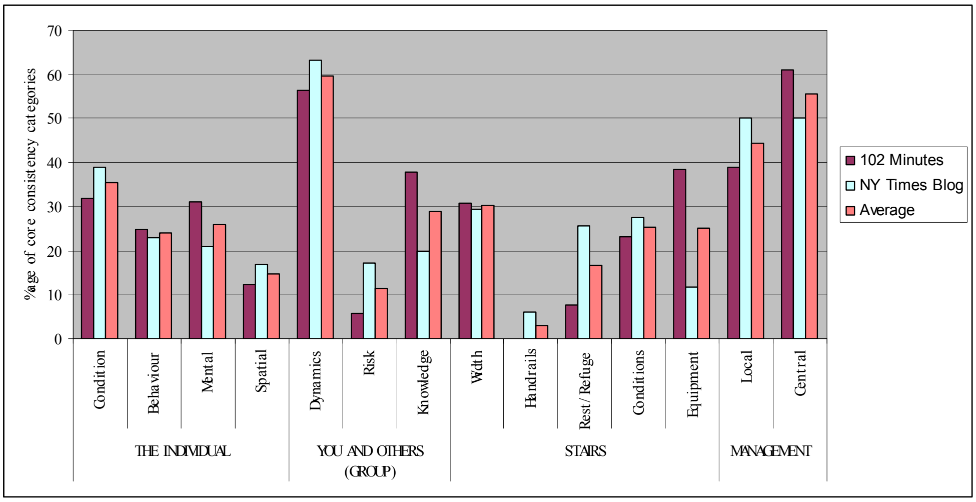


Figure 6-6: Graph of Category Percentages relative to each Core Consistency

Figure 6-6 shows some interesting directions within each core consistency. These are discussed below for each study and then as an average across the two studies. There is an internal pattern for each of the core consistencies so that generalisations can be made (Yin, 2009; Hak and Dul, 2009 and Tellis, 1997). It should be noted in this instance that the pattern matching technique is not being used as a means of testing a hypothesis but rather to compare patterns arising out of two disparate studies (Yin, 2009 and Hak and Dul, 2009).

Category Order	102 MINUTES	NY TIMES BLOG	
	You (Individual)		**Comments**
Most	Condition	Condition	
Mid	Mental	Behaviour	*Similar categories occur within the mid range*
Level	Behaviour	Mental	*although percentages differ slightly*
Least	Spatial	Spatial	
	You & Others (Group)		Comments
Most	Dynamics	Dynamics	*Pattern coincides exactly*
Mid	Risk	Risk	
Level			
Least	Knowledge	Knowledge	
	Stairs		Comments
Most	Equipment	Width	*Pattern is slightly different but width is second in 102 Minutes and first in NY Times Blog*
	Width	Conditions	
	Conditions	Risk Refuge	*Mid range differs in terms of order but variances are small*
	Risk/Refuge	Equipment	
Least	Handrails	Handrails	*handrails are the lowest by a clear margin*
	Management		Comments
Most	Central	Central/ Local	*There is no distinct pattern other than a 60:40 split with Central being the*
			most prevalent would not be out of order given that local is normally subservient to central
Least	Local	NA	*organisation e.g. AS 3745-2011 and Dwyer and Flynn (2004).*

Table 6-3: Ordering of Core Consistency Categories for 102 Minutes and NY Times Blog

The internal patterns[159] within each core consistency appear from the ordering of the factors from each. Following the results shown in Table 6-3 the patterns for the “Individual” and the “Groups” match after a fashion except for the mid-range ordering for the “Individual”. The patterns for the remaining two core consistencies, “Stairs” and “Management” are not as consistent. The “Width” category for “Stairs” is the most predominant category for the “NY Times Blog” study and the second most predominant category for the “102 Minutes” study so that there is a “pattern” of sorts seeing the least predominant factor was “handrails”. The latter matches the findings across the eight buildings in the Exploratory Case Study. Also the statement that stair width is an important issue matches findings of other post WTC 9/11 studies (Peacock et al, 2009 and Blair, 2010). The claim that there is a distinct pattern for Management could be challenged in that there are only two categories centred on the emergency management organisation. There is

[159] Patterns are seen here as trends. This is explained by the use of the term “ordering

an even 50:50 split between local and central roles, procedures and respondent (individual) expectations for the "NY Times Blog" and an approximate 60:40 (Central: Local) split for the "102 Minutes" study where Central was the predominant factor because of the role of the Port Authority and the size of the tenants. Comment 102.20 underpins this factor even where major Tenants (J.P.Morgan) were involved. Although the impact was to have the employees move toward to exits and into the stairs this was still in conflict with some of the instructions being given from the Central emergency management organisation (see Comment 102.20 below):

Comment 102.20

"The instruction to the caller from Morgan Stanley was especially important. Morgan Stanley occupied twenty two floors and over 2000 people worked for the company. An executive for the bank, Ed Ciffone, had overseen years of intense evacuation programmes, and one of his deputies, Rick Rescorla, had led the drills with a zeal that seemed near evangelical. ... Now it made sense. Their wardens pulled out megaphones and began to drive the Morgan staff out of the building."
Dwyer and Flynn (2004, p.72). Shows the impact of a committed prepared organisation that also comprised a large tenant. Groups here were most likely a mixture of work colleagues from a particular department or team and those formed in transit to the stairs following the warden's instructions. The core consistencies involved were "Groups" and "Management". If this comment is read in conjunction with comment 102.19 then the potential conflict can be seen with central management directions.

The most predominant category within the "You" (Individual) core consistency was Condition which comprised the following:

- Obesity (YC1)
- Fitness (YC2)
- Strength (YC3)
- Co-morbidities affecting stance and gait (YC4)

This underpins the aim of the PhD Case Study where the physical challenge of descending multiple flights of stairs is seen as being based on the stair user's or occupant's fitness and strength. Lack of fitness results in obesity (Booth et al, 2002). Lack of fitness combined with ageing will lead to loss of strength especially in relation to stability and to a certain extent in dynamic or aerobic capacity (Reeves et al, 2008). Functional limitations also play a role in the stair user's / occupant's confidence in going down the stairs and are not only mirrored in their descent speed but also the distance they have to travel (Spearpoint and MacLennan, 2012). Other elements from the mid-range of categories deal with mental, neurological and behavioural factors which can also affect descent speed and the confidence that people may have that they can complete the challenge (e.g. fear of falling). The latter is often reflected in the degree to which the people rely on the use of the handrail (Reeves et al, 2008a). It is interesting to note here the low ordering of handrail use. This reflects the finding of the Exploratory Case Study in that the majority of the respondents did not appear to rely on the handrail for support. Even the support of others does not provide the user with the mental strength and belief in themselves to complete the "journey" (see comment 102.65 of the "102 Minutes" Study).

An interesting comparison required at this point to filter the "You" or "Individual" results is one with the work of Shields et al (2009) on the behaviour and evacuation experience of WTC9/11 Incident evacuees with self designated mobility impairments. One factor that is missing in the author's "102 Minutes" study is a measure of the respondent's descent speed so as to determine the impact of the functional limitation. This is discussed in the context of the group in a subsequent paragraph.

The pattern for "You and Others" is in complete agreement between the two studies and therefore can be generalised across the 2008-2010 case study. The most predominant category is group dynamics. Altruism or, being prepared to assist, is the most predominant element within the "group dynamics" category which corresponds with the findings of the content analysis carried out of media reports by Fahy and Proulx (2005). Cohesion and the risk of assisting others were also considerations but were over shadowed by the preparedness of group members to help others. These two studies did not contain any information about the frequency of group formation as compared with the Exploratory Case Study.

It is important to know where the groups were formed and whether they were primary or affiliate groups. Shields et al, (2009) mention primary and affiliate groups. The primary group they showed was one formed by an individual with functional limitations who required assistance. The affiliate group is one that can attach itself to the primary group. It is unclear where this attachment is formed. The studies (Dwyer and Flynn, 2005 and Parker-Pope, 2008) showed groups maintained their membership when they comprised colleagues from the same department, most likely working in the same location. The Exploratory Case Study showed that there was a marked increase in groups formed within the stairwell as opposed to "on the floor".

Cohesion is related in a fashion and perhaps the degree of bonding between the members of the group and one would expect the degree of altruistic behaviour. This is not the case when one considers the context of "Comment 102.24" from the 102 Minutes Study (Dwyer and Flynn, 2005) where the respondent who in fact was overtaking at random but when he came across the "heavy" woman on the 10^{th} floor he stopped and assisted her for the next 10 storeys. A bond was formed and it could be argued so was a group. Perhaps groups are transient as argued by Shields et al (2009) so that the context of each evacuation needs to be explored carefully before generalisations can be made. This also applies to the "permeability" of group territory (Lindskold et al, 1976). Permeability needs to be considered with spatial distribution of the members when intrusion by a separate "aggressive" individual typified by certain attitudes in the "NY Times Blog" Study who may wish to overtake. Comment 102.24 (see below) shows that the heavy woman may or may not have been attached to a group. The members of the group may not be able to assist but the young man who may have initially classified as "aggressive" was allowed to penetrate the group boundaries to assist the woman (altruistic) behaviour. It could be argued that this man in fact became part of a primary group.

COMMENT 102.24
"The single-minded abandon of Michael Sheehan's departure ....should have carried him clear of the tower by 9:02, but several developments managed to slow him down...When he came across a heavy woman...at the 10th floor, Sheehan ....walked down with her ....out of the building."
Dwyer and Flynn (2004, p.90). Shows that overtaking occurred so that single-minded behaviour may have been initial behaviour but this was placed by altruistic behaviour with the large woman whom he assisted for 10 floors until they were out of the building. The applicable core consistencies are "You", "Group" and "Stairs". Overtaking did occur so that Sheehan may have moved through group territories. A group was formed in the stairs and on other occasions may have slowed others behind as the group would have occupied the stairs. Rest space would have been appropriate and the stairs were not wide enough as demonstrated by others (Peacock et al, 2009).

The 102 Minutes Study also shows the extent to which the groups may in fact have been formed by management which was also shown to be the case in Building 4 from the Exploratory Case Study. In this instance the groups are generally larger (10+ persons) so there may be a greater tendency for group members to "peel off". If management adopts a procedure where the group is led and followed by wardens then this may not occur. Cohesion would also be a challenge as many of the members would not be immediate colleagues. The roles would also be completely different as the wardens may be seen as the leaders and decision makers.

Altruistic behaviour underpins some of the objectives associated with a primary group (Shields et al, 2009) where assisting an individual such as

Participant E in the Shields et al Study (2009) may be risky when the other members of the Group are not trained. Participant E was a 54 year old female with a BMI of 38 who had severe arthritis of the knee and who did no regular exercise. Participant E lacked stair confidence because of her fear of falling and this most likely would have added to her reduction in speed as well which is equivalent to 0.9 storeys per minute or approximately 0.2m/sec. This would have slowed the group down which appears to have disbanded somewhere else but it does provide a challenge as the other members of the group may not have been strong enough to carry her. Perhaps this was the same scenario as that associated with Comment 102.24 in the "102 Minutes Study".

As previously discussed the most predominant category within the "You" (Individual) core consistency was Condition. The "You" or "Individual" core consistency was the most predominant in the NY Times Blog Study where the respondents were individuals and the theme to do with fitness or the lack thereof. The emphasis on Condition within this core consistency provides the "cue" to link the discussion for this section on "You" or the "Individual" with the Focus Group member responses and to examine these in terms of capability or functional ability. Fritz (2009) shows that reduced movement speed is the most reliable predictor of functional ability. Other studies of ageing and loss of strength are also reflected in slower speeds. The ability to walk increased distances (Hulens 2003 and Spearpoint and MacLennan 2012) is also a vital factor and needs to be considered with the travel speed. The Specialist Focus Group members either have BMI's > 30 or are over the age of 45 years so that their functional limitations will provide a better context for discussion.

The "Management" core consistency was the most predominant in the 102 Minutes Study and provided valuable insights into employee/ employer relations especially in terms of the commitment of J.P.Morgan where they viewed their employees as their main asset. They were reminded of the 1993

Bombing experience and held frequent trial evacuations. Groups naturally formed when the wardens sprang into action when convinced there was a problem. J.P.Morgan had over 2000 employees and therefore their local management/evacuation procedures could override lack of initiative or information from the central emergency management organisation. Many of the responses from survivors were critical of management so that the impact of their decisions and strategy on group formation, provision to be made for those with functional limitations and the maintenance of the stair environment are extremely relevant. These issues will also be revisited under the Focus Group section.

The "Stair" core consistency was the least predominant. The main category within this core consistency dealt with the width of the stairs. Shields et al (2009) commented that stairs should be wide enough for navigating by those with functional limitations. Stairs in Towers 1 and 2 (Figure 6-7) were found to be too narrow (Pauls et al, 2007, and Averill et al, 2005). This finding was in terms of flow. Shields et al (2009) recommends 1200mm but this would require two handrails for those with functional limitations as commented in the "NY Times Blog" responses. It is interesting to note that Pauls et al (2007) recommend a wider stair of the order of 1500mm. Once again the concern here for those with functional limitations would be reach. Participant E's[160] body ellipse is not known although it could be calculated from the height and BMI (MacLennan et al, 2008) using data from "CT Scan Imaging" spread sheets (Geraghty and Boone, 2003) that would even challenge the 1200mm width when Participant E required assistance. This would be the case for the person in Comment 102.24 from the 102 Minutes Study (Dwyer and Flynn, 2005). There is a real need therefore to resolve this issue which is additionally supported by Peacock et al (2012).

[160] Refers to Participant E in the Shield et al Study (2009)

Figure 6-7: Part view of typical WTC Stair – Content Analysis One

(Source: Labriola, J., (2003), *Walking Forward Looking Back: Lessons from the World Trade Center: A Survivor's Story*, Hydra Publishing pp. 41.

6.5.3 Concluding Remarks on Context Analysis Discussion

A conclusion cannot be made at this point as the **context** needs to be widened to include the Focus Group results and discussions in the next main section. The discussion in this section has summarised the issues to be included in the subsequent sections on the Focus Groups. This centres around using the descent speed as an indicator of functional limitations (Delphi Group advice) and to a certain degree confidence associated with posture and balance as demonstrated in the resources model of Horak (2006).

6.6 The Focus Group Studies 1: Benchmark BMI Focus Group

There are three Focus Group Studies[161] as described in Chapter 3 being:

- BMI Benchmark Group comprising 10 "young" office workers below the age of 40 years and one 40+ years who undertook a vigorous level of exercise in accordance with the IPAQ (Sjostrom et al, 2005) and was therefore classified as "fit".
- " Larger Figure" Focus Group comprising office workers with a BMI classification of overweight+(WHO, 2011) and who were conversant with trial evacuations being part of a building set up where the emergency control organisation was actively committed to full scale practices and had a limited functional limitation classification procedure in place that encompassed the model put forward by Matheson (2003).
- "Mature-Age Office Worker Focus Group comprising office workers with an age over 45 years of age (Kossen and Wilkinson, 2010) from the same building set up as the "Larger Figure" Focus Group. The BMI of this group varied as age was the sole criterion.

The "BMI Benchmark" Focus Group comprised observers from the 2008-2010 case studies so that they were immersed in the gathering of data and were conversant with respondent occupant trial evacuation behaviour and stair use. The two other focus groups were selected from workers in the Sydney

[161] The three focus groups that represent the spectrum of performance according to the literature according to Ayis et al and which will provide comparative data on descent speed as an indicator f functional limitations. The benchmark group is of young adult office workers who are fit as measured under the IPAQ system (Sjostrom et al, 2005)

Building M6, one of the buildings studied in Cycle PDSA 3 of the 2008-2010 Case Study. A validated self reporting survey form as part of the questionnaire integrating the IPAQ Short Form (Ottevacre et al, 2011 and Sjostrom et al, 2005) was used to gather further information so as to make the results more comparable with that from the PDSA Cycle 3 of the2008-2010 Case Study. A BMI Benchmark Focus Group provides a better view of the context when reviewing similar recent studies connected with the WTC 9/11 incident and associated research programmes (Galea et al, 2008 and 2008a; Peacock et al, 2009; Jiang et al. 2012; Boyce et al, 2011 and Peacock et al, 2012) when looking at actual descent speeds as opposed to those masked by extensive delays or density.

6.6.1 Introduction

There were two sites for the BMI Benchmark Group[162]. The first was a 20 storey office building in Christchurch, NZ with scissor stairs (Figure 6-8). The second was the 32 storey office building which is Building M6 in the 2008-2010 Case Study.

Each member of the group recorded their descent on a Dictaphone. The participants were fit with their fitness having been measured using the IPAQ system (Sjostrom et al, 2005). There were a total of five in the Christchurch group and five in the Sydney group (total of ten members in the BMI focus group).

[162] The buildings were selected as being representative of the 2008-2010 case study building profile. The Christchurch building was 20 storeys which was less than the 25 storey measure of 50% of the population in the Exploraory Case Study and also representative of Building M4 and the other being M6 which was one of the highest buildings in the case study. Also two sites were used because of the dofferent types of stairs in terms of the number of turns per storey.

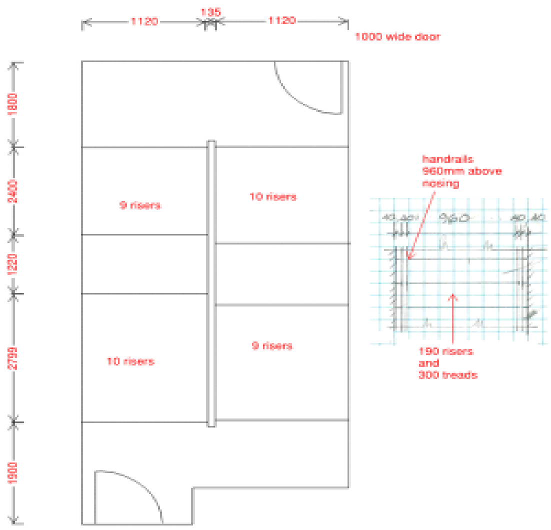
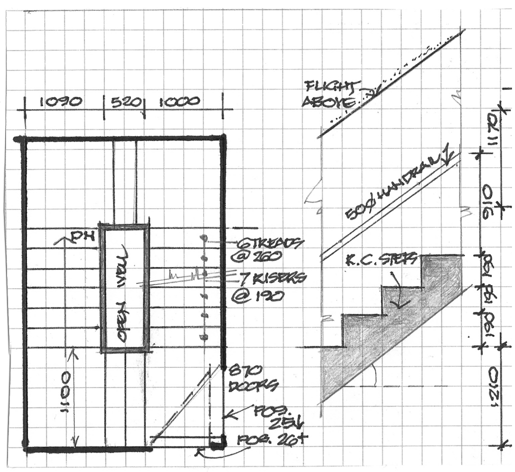


Figure 6-8: Diagrammatic Plan View of Stair 1 Christchurch Building (Represents M4)



Diagrammatic Plan view - Stair One

CALCULATIONS

Storey height = 19X 190mm = 3.610m

Distance traversed = 9.058m per storey / 244.6m

Total traversed height to level 5 = 97.470m

Figure 6-9: Stair One Building M6

M6 was used for the Sydney Group of 5 members. Stair 1 (Figure 6-9) was the stair selected and represented a steep stair of 37^0. Rich views (Templer 1992) provided a distraction through the wide void and there were four changes in direction per storey as compared with one in Christchurch building.

The 5 group members were all fit being assessed as before. One member of the group was over the age of 40 years but played tennis and exercised regularly

Results are presented in the subsequent subsections for their use as the benchmark.

6.6.2 Results From Observations and Dictaphone Recordings

Results are presented for each site comprising:

- Table of individual characteristics gathered from completed questionnaire.
- Table of stair descent times and speeds on a storey by storey basis – mean speeds are shown so that they can be compared directly with other studies in the discussion section.
- Regression of no. storeys coped vs. fitness level.

Christchurch Site

SCHEDULE OF PARTICIPANTS' INDIVIDUAL CHARACTERISTICS										
Participant No.	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**
Age	33		32		39		26		29	
Gender	m		m		m		m		m	
Height	1830		1800		1651		1980		1760	
Mass	87		70		86		91		80	
BMI	26		21.6		31.6		23.2		25.8	
waist size	864.0		820		864		889		813	
Foot size	8.5		9		8		13		10	
no. storeys cope	**40**	**(IPAQ)2**	**35**	**(IPAQ)2**	**40**	**(IPAQ)2**	**200**	**(IPAQ)3**	**20***	**(IPAQ)1**
*** lower number storeys as this person has problem with the definition of each step after turning through 20 floors - he wears spectacles.**										
	Indicates uinclusion of vigorous exercise									
	walking only exercise									

Table 6-4: Christchurch Site – Individual Characteristics

(R^2=0.72 with a reasonable level of significance <.01)

Table 6-4 above shows the intrinsic characteristics of the five members of the Christchurch BMI Benchmark Focus Group. The participants are all male and below the age of forty five years. Participant three is classified as obese but this is due to a muscular stature gained as a result of playing competitive rugby league. Participant four has a shoe size of UK 13. All waist circumferences are less than 900mm which is a more meaningful measure than BMI (Serrano-Sanchez et al, 2010) as it takes into account adiposity[163].

The following factors may influence the individual descent times:

- Knee injury from sport for participant 3. BMI not seen as an issue because waist circumference was less than 900mm.
- Participant 5 did not exercise and had reduced vision.
- Participant 4 had size 13 (UK) feet which prevented him from facing front on when going down the stairs.

BMI BENCHMARK STAIR DESCENT GROUP 1 - CHRISTHURCH													
Distance traversed per storey = 8.423m ; Total distance = 168.5; height per storey = 3.420mm ; total height 64.980mm													
Participant No.	1	1	2	2	3	3	4	4	5	5	Average	Average
Time refs	Cum. Time	Des. Speed	Cum. Time	Des. Speed	Cum. Time	Des.Speed	Cum. Time	Des.Speed	Cum. Time	Des.Speed	Cum time	Descent Speed
Floor	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec
G	156	1.05	190	0.94	158	0.94	153	1.05	196	0.94	171	0.99
1	148	1.05	181	0.94	149	0.94	145	1.05	187	0.84	162	0.99
2	140	1.05	172	0.94	140	0.84	137	0.94	177	0.84	153	0.94
3	132	1.05	163	0.94	130	0.94	128	1.05	167	0.84	144	0.99
4	124	1.20	154	1.05	121	1.05	120	1.05	157	0.94	135	1.09
5	117	0.94	146	0.77	113	0.94	112	0.94	148	0.84	127	0.89
6	108	1.05	135	0.94	104	0.94	103	1.05	138	0.77	118	0.99
7	100	1.20	124	0.84	95	0.84	95	1.05	127	0.84	108	0.98
8	93	1.20	114	0.94	85	0.84	87	1.05	117	0.84	99	1.01
9	86	1.05	105	0.84	75	1.20	79	1.05	107	0.94	90	1.04
10	78	1.05	95	0.94	68	1.05	71	1.20	98	0.94	82	1.06
11	70	1.05	86	0.94	60	1.40	64	1.05	89	0.94	74	1.11
12	62	0.84	77	0.84	54	1.05	56	1.20	80	0.84	66	0.98
13	52	1.05	67	0.84	46	1.40	49	1.20	70	0.84	57	1.13
14	44	1.20	57	0.94	40	1.20	42	1.20	60	0.84	49	1.14
15	37	1.20	48	0.94	33	1.20	35	1.20	50	0.94	41	1.14
16	30	1.05	39	0.84	26	1.20	28	1.40	41	0.94	33	1.13
17	22	1.20	29	0.94	19	1.40	22	1.20	32	0.77	25	1.19
18	15	1.20	20	0.84	13	1.20	15	1.05	21	0.84	17	1.08
19	8	1.05	10	0.84	6	1.40	7	1.20	11	0.77	8	1.13
20	0	1.05	0	0.84	0	1.40	0	1.20	0	0.77	0	1.12
Average DS		1.09		0.90		1.11		1.12		0.86		1.01
	Cells highlighted thus indicates Participant 3 slowing because of knee injury											

Table 6-5: Christchurch Site Descent Speeds

163 Loosely defined as "fat" distributed around the central region of the body> The person is obese.

The results in Table 6-5 above do not reflect the functional limitations mentioned under the bullet points in the previous paragraph. Participant 5 was however the slowest (196 seconds) so that there was some impact due to possible lack of fitness and reduced vision. Descent speeds ranged from 0.77m/sec at the start, “learning the stair”, increasing to a peak of 0.94m/sec over the mid-levels down to 0.84m/sec due the onset of fatigue. Participant three did not show any major signs although the knee injury did slow the descent from level 8 onwards although he made the comment about the pain at level 6.

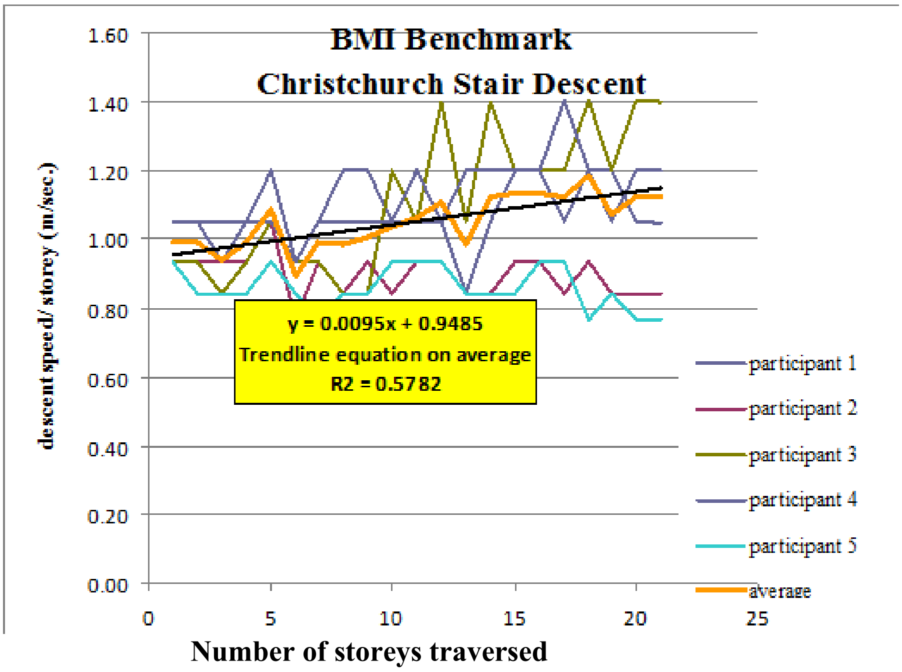


Figure 6-10: Christchurch Site – Distribution of Descent Speeds[164]

[164] Trendline shows a general slowing down.

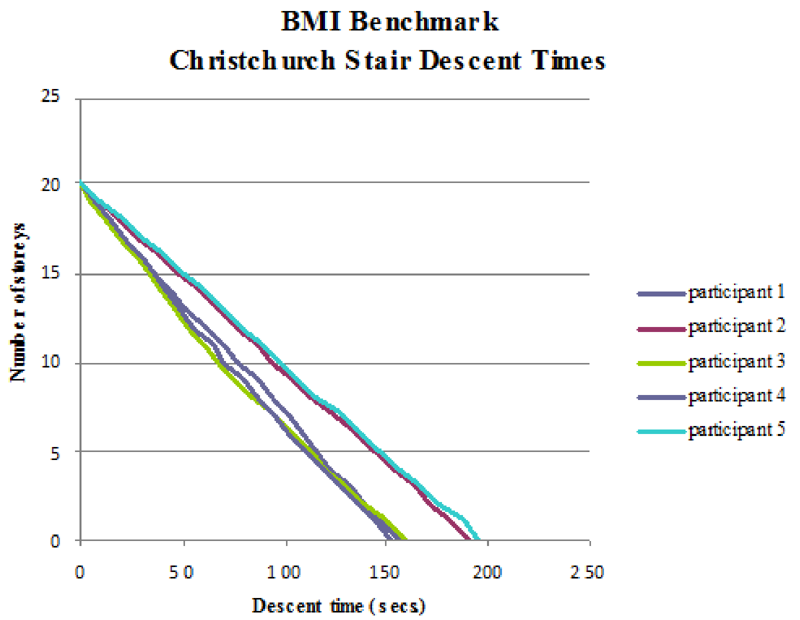


Figure 6-11: Christchurch Site – Stair Descent Chart

Figure 6-11 shows two clusters of descent times. The cluster with the shortest times varies from 153 seconds for participant 4[165] to 158 seconds for participant 3. The latter was prepared to work through the pain for the last seven storeys.

The trend line in Figure 6-10 shows a general slowing down across all five participants which is consistent with the Sydney Sub Group (speed = .0095x(distance traversed) + 0.9485). This equation accounts for 58% of the variance. This also agrees with observations made by Shields et al (2009) although these observations related to people with a number of functional limitations. The number of storeys in this situation was 20 which will be shown in the 2008-2010 Case Study to be an apparent limiting barrier for many with functional limitations.

[165] Foot size did not pose any problems with placement due to the tread size being 300mm

Sydney Site

SCHEDULE OF PARTICIPANTS' INDIVIDUAL CHARACTERISTICS										
Participant/Gender	Participant 1 - Male		Participant 2 - Female		Participant 3 - Female		Participant 4 - Male		Participant 5 - Male	
Age	31		35		30		24		24	
Gender	m		f		f		m		m	
Height	1880		1650		1730		1870		1910	
Mass	90		74		62		67		70	
BMI	25.5		27.2		20.7		19.2		19.2	
waist	864.0		800		770		740		740	
Foot size	12		8		5		9		7.5	
No storeys cope	32+	3	32+	1	32+	3	50	1	50	2
	Indicates inclusion of vigorous exercise - Participant 3 - this did not include walking									
	walking only exercise									

Table 6-6: Sydney Site – Intrinsic Characteristics

(R^2=.611 with a reasonable level of significance <.01)

Table 6-6 shows some relevant physical individual characteristics for the five members of the Sydney BMI Benchmark Sub Group. There are two female and three male participants. All participants except for one male are below the age of 40 years. Participant number four does not exercise regularly. Participant number two has a BMI that is classified as overweight and yet undertakes a vigorous exercise regime as designated in the IPAQ short form (Sjostrom, 2005). She does have asthma. Participant one has large feet (UK 12). All waist sizes are well under 900mm for males and 800mm for females which is a more meaningful measure than BMI (Serrano-Sanchez et al, 2010) on the basis of adiposity.

BMI BENCHMARK - STAIR DESCENT- STAIR 1 - GROUP 2 - SYDNEY												
Distance traversed per storey =9.058 m ; Total distance = 244.6m; storey height = 3.610m; total height = 97.47m;												
Participant No.	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**Average**	**Average**
Time refs	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**
Floor	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)
5	199	1.29	359	0.65	242	1.01	328	0.75	295	0.75	285	0.89
6	192	1.29	345	0.65	233	1.13	316	0.82	283	0.75	274	0.93
7	185	1.29	331	0.75	225	1.13	305	0.75	271	0.75	263	0.94
8	178	1.13	319	0.60	217	1.01	293	0.75	259	0.70	253	0.84
9	170	1.13	304	0.65	208	1.01	281	0.70	246	0.82	242	0.86
10	162	1.01	290	0.65	199	1.01	268	0.70	235	0.70	231	0.81
11	153	1.13	276	0.65	190	1.01	255	0.75	222	0.75	219	0.86
12	145	1.29	262	0.65	181	1.01	243	0.70	210	0.75	208	0.88
13	138	1.29	248	0.65	172	0.91	230	0.75	198	0.82	197	0.89
14	131	1.29	234	0.70	162	0.91	218	0.75	187	0.75	186	0.88
15	124	1.13	221	0.60	152	1.01	206	0.70	175	0.91	176	0.87
16	116	1.13	206	0.65	143	1.01	193	0.82	165	0.82	165	0.89
17	108	1.13	192	0.70	134	1.01	182	0.70	154	0.82	154	0.87
18	100	1.29	179	0.65	125	1.01	169	0.82	143	0.82	143	0.92
19	93	1.29	165	0.65	116	1.01	158	0.70	132	0.82	133	0.89
20	86	1.13	151	0.60	107	1.01	145	0.82	121	0.82	122	0.88
21	78	1.29	136	0.65	98	1.01	134	0.70	110	0.82	111	0.89
22	71	1.13	122	0.70	89	1.13	121	0.70	99	0.91	100	0.91
23	63	1.13	109	0.70	81	1.13	108	0.75	89	0.91	90	0.92
24	55	1.29	96	0.70	73	1.01	96	0.75	79	0.82	80	0.91
25	48	1.13	83	0.75	64	1.01	84	0.75	68	1.01	69	0.93
26	40	1.29	71	0.75	55	1.01	72	0.75	59	1.01	59	0.96
27	33	1.29	59	0.70	46	1.01	60	0.75	50	0.82	50	0.91
28	26	1.13	46	0.75	37	1.01	48	0.75	40	1.01	39	0.93
29	18	1.29	34	0.75	28	1.01	36	0.75	31	0.91	29	0.94
30	11	1.51	22	0.91	19	1.01	24	0.75	21	0.82	19	1.00
31	5	1.81	12	0.75	10	0.91	12	0.75	10	0.91	10	1.03
32	0	1.81	0	0.75	0	0.91	0	0.75	0	0.91	0	1.03
Average DS		**1.26**		**0.69**		**1.01**		**0.75**		**0.84**		**0.91**

Table 6-7: Sydney Site Descent Times and Speeds

Table 6-7 shows the descent times and speeds for the 32 storeys. Points of interest are:

- Participant one undertook a vigorous exercise regime, had a BMI of 25.5 and a waist measurement less than 900mm. His average descent speed was 1.26m/s as compared with the 1.2m/s presented by Shields et al (2009) and Fahy and Proulx (2001).

- Participant two also undertook a vigorous exercise regime but has asthma. She has an 800mm waist measurement but no signs of adipose tissue. Her descent speed was the slowest at an average of 0.69m/s and was actually overtaken by participant three although starting 60 seconds later. Her comments on the sound file indicate problems in the vicinity of level 24.

- Participant three undertook a vigorous exercise regime regularly playing netball. Her waist measurement was less than 800mm. Her descent speed was the second fastest out of the group at an average of 1.01m/s and she overtook participant two.

- Participants four and five, both male, were almost completely identical in physical characteristics and although participant four reported that he did not exercise regularly his descent speed did not decrease with distance whereas participant five seemed to tire from level 16 downwards. No reason was provided for this either on the questionnaire or from his comments on the sound file.

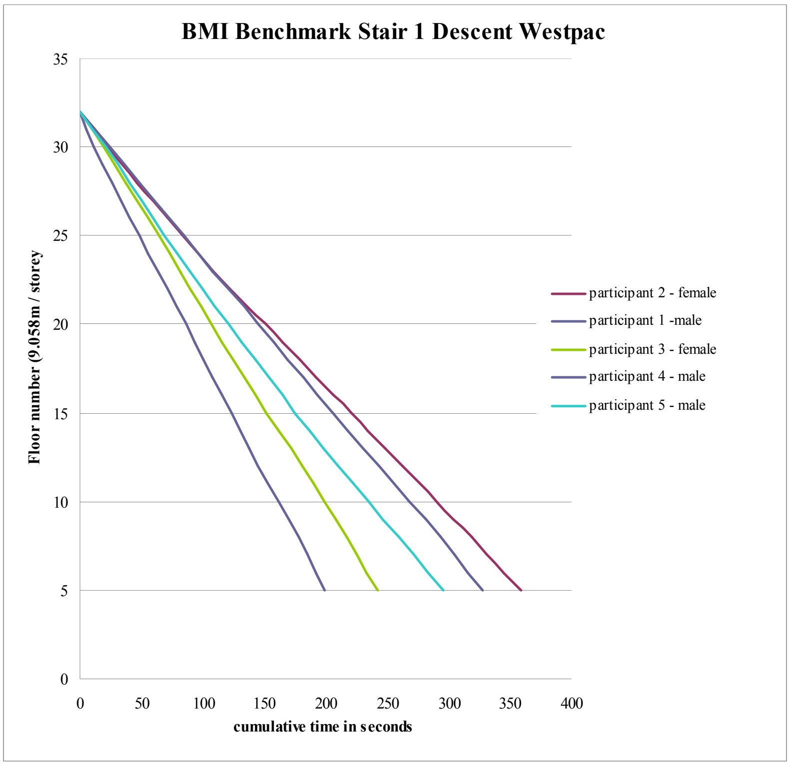
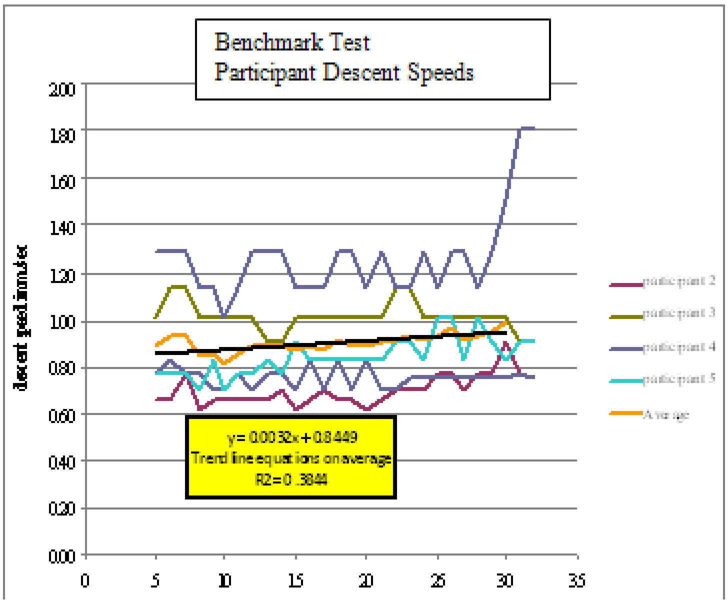


Figure 6-12: **Sydney Site Descent Times**



Number of storeys traversed

Figure 6-13: Sydney Site Descent Speeds

As shown in and Figure 6-12 and Figure 6-13 the variance in descent speeds may reflect the functional limitation of participant two. The overall trend in descent speeds is a slowing down due to the number of storeys (descent speed = 0.0032 no. storeys + 0.8449). This only accounts for 38.44% of the variance which is still moderately significant ($p<.05$). Once again this matches comments made by Shields et al (2009) in terms of slowing down although their comments are made in the context of those with functional limitations.

When the results from Figure 6-14 are examined across the two sites the trend line equation alters slightly with the descent speed = 0.0027*no. storeys + 1.057 but it still indicates a small reduction in speed related to distance or height traversed. Overall the benchmark trend is still between 1.00 and 1.2m/sec which is in line with those suggested by others (Shield et al 2009 and Fahy and Proulx, 2001). The results of the survey for both the Sydney and Christchurch BMI

Benchmark Sub Groups are presented in the next sub section, "Combined BMI Benchmark Group Questionnaire Ratings".

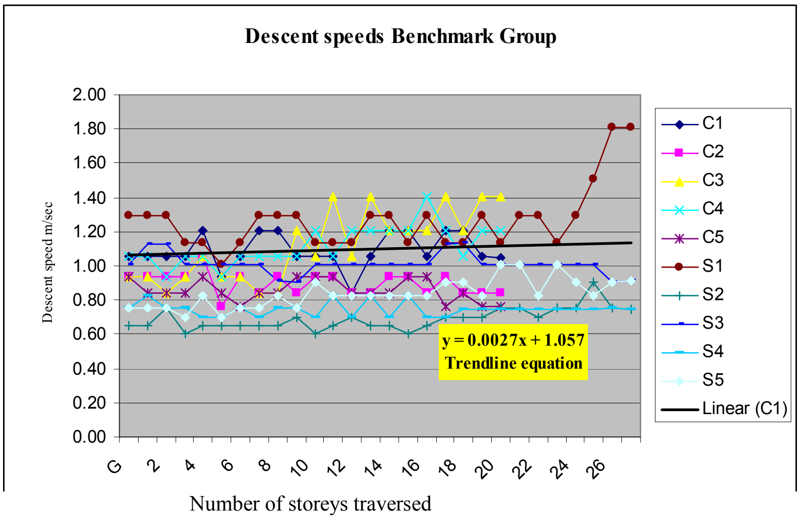


Figure 6-14: Combined Descent Speeds

6.6.3 BMI Benchmark Survey and Discussion Results

Refer to Figure 6-8 and Figure 6-9 for the details of the stairs for the two sites. The Sydney stairs are poor in terms of pitch, width of tread, legibility and availability of suitable handrails. Another possible problem with the Sydney stair already mentioned above is width of the void between the flights in terms of "rich views" (Archea et al, 1979). On the other hand the Christchurch stairs are seen as being reasonably comfortable and legible with two handrails and a minimum number of turns per storeys.

BMI Benchmark Group Members Stair Descent Experience Schedule

Participant / Element	S*1	S*2	S*3	S*4	S*5	C*1	C*2	C*3	C*4	C*5
Health Condition	None	Asthma	None	Poor Vision	None	None	None	Knee cartilage	None	None
Falls	None	None	One	None	One	None	None	None	None	None
Handrail easy	1	2	1	1	2	1	4	1	1	1
Step legibility	2	4	1	1	2	1	2	1	2	1
Too Steep	5	2	5	4	5	4	5	4	5	4
Narrow treads	2	2	4	4	4	4	1	5	2	2
Too many flights	5	5	5	5	5	5	2	4	4	5
Lower limb discomfort	5	5	5	1	4	5	2	2	2	5
Fear of fall	4	5	5	5	5	4	5	4	5	5
Dysponea	5	5	4	5	5	5	5	2	5	5
Chest discomfort	5	5	5	5	5	5	5	5	5	5
Fatigue	5	5	5	4	5	5	5	2	4	5

S = Sydney test; C = Christchurch test; Scale: 1= strongly agree; 2= mildly agree; 3= neutral; 4= mildly disagree; 5= strongly disagree

Legend and comments

- *Participant S1, male, with size 12 shoes found steps too narrow so that he placed feet at 45⁰*
- *Participant S2, female with size 8 shoes found steps too narrow, steep and illegible after while*
- *Participant C2, male with size 9 shoes found 300mm treads too small and had sore knees*
- *Participants C4, male, size 10 shoes found 300mm treads too small/ calves hurt and C5, male with size 13 shoes found 300mm treads too small.*

Table 6-8: BMI Benchmark Focus Group Questionnaire and Discussion Responses

The responses from the Group are summarised in Table 6-8 above. The following triangulation comments are made using the comments from the completion of the IPAQ questionnaire by the members of the group:

- **Christchurch Stairs**
    - **Handrails** did not agree they were easy to use. No functional limitations. Most stated lack of contrast.
    - **Step legibility** – all were in agreement.
    - **Too steep** (32.33^0) – most disagreed so that pitch was acceptable.
    - **Treads too narrow** – 3 out of 5 participants agreed and this triangulates well with the minimum shoe size of the group which was a UK 9. Other two participants were satisfied and their shoe sizes were less than 9.
    - 4 out of the five participants thought that the **number of flights** were manageable which seems to agree with the 20 storey barrier found in the Exploratory Case Study.

- **Sydney Stairs**:
    - **Handrails** – only one set provided and all agreed that it was at the right height and was graspable. This included participant two who used them.
    - **Step legibility** – 4 out of 5 were in agreement but participant 2 with the asthma did not agree. Lack of contrast in assessment.
    - **Too steep** (37.33^0) – only participant 2 agreed with this which does not support the scale in the New Zealand Compliance Document D1 (DBH, 2006, p4). AS 1428.1:2009[166] would partly support participant 2 being the Australian Access Standard.
    - **Treads too narrow** – 2 out of 5 participants agreed and this triangulates well with the maximum shoe size of the remaining group being UK 9. Participant 2 was concerned with foot placement but her foot size was not the issue. Participant 1 had size UK12 shoes but also the fastest descent rate. He still had problems with foot placement.
    - As would have been expected **32 storeys was acceptable** except that participant 2 would most likely require places to rest because of the asthma. This is merely an observation.

In line with the aim for "the number of storeys that participants could cope with" correlated with their IPAQ exercise ratings (Sjostrom et al, 2005) the findings for the BMI Benchmark Sub Groups are:

- Christchurch – R^2=0.72 and $p<.05$ so that exercise rating for this group could predict 72% of the variance of number of storeys.

[166]Standards Australia (2009)

- Sydney - $R^2 = 0.6$ and $p<.05$ so that exercise rating for this group could predict 60% of the variance of the number of storeys.

These results are only for small samples with a moderate level of significance. Adjusted R^2 values would be less. The only support may be found in the slowing down in descent speeds as a direct function of the number of storeys (distance traversed) summarised in Figure 6-14. As far as the BMI Benchmark Group is concerned the critical issue is the width of the treads followed by the pitch of the stairs. This may alter for the Fuller Figure and Mature Age Focus Group which may be found in the next section.

6.7 Focus Group Study 2 – Fuller Figure

6.7.1 Introduction

The office building from which the two specialist focus groups (see next section for the Mature Age Focus Group Study) were drawn from was Building M6 of the 2008-2010 Case Study. It was not possible to measure descent speeds for the members of these two groups for health and safety reasons. The descent speed was calculated from a walking test based on the work of Reiner et al (2002) and Fujiyama and Tyler (2010). A walking test was of 40m was applied which was converted to represent an average stair descent speed from studies on the relationship between the walking speed and descent speeds (Reiner et al, 2002 and Fujiyama and Tyler, 2010)[167]. There is no doubt that fatigue could be taken into account based on the distance travelled using the same basis as suggested by Spearpoint and MacLennan (2012). This approach approximates that used in the six minute walking test which shows up the impact of functional limitations including fitness (Hulens et al, 2003).

[167]Triangulated with the author's own stair descent speed

6.7.2 Results – Coding of Initial Comments

Note: Compared with the comments under Content Analysis these comments refer to the individual themselves specifically and therefore will complement the Content Analysis Discussion because of the members' perception of themselves.

The initial comments from the Fuller Figure Focus Group Members may be found in Table 6-9 to Table 6-12 below[168]:

Table FF 1 Participant No.	Gender	***YOU ELEMENT*** Condition (Coded)	Element YOU	You/ Others	Stairs	Any/ else	Comment
A (J)	F	Knee	✓				• Knee reconstruction • Often tired • Often stressed
B(W)	M	0	✓				• Nothing to add
C(L)	M	Reduced Vision	✓				• Wrinkled retina – difficulty with depth perception – blurred vision • Difficulty locating steps • Last step in each flight – trips • Lack of step marking causes problems
D(M)	M	Knees/ Height/large feet	✓				• Big feet – difficulty with small steps • Crabs down stairs – relies on handrails for stability • Sore knees but can withstand pain – limit in no. storeys • Lot slower after say 15 storeys
E(?)	M	Not fit Arthritis	✓				• Extremely unfit • Arthritis in knees which compromises no. of storeys that he can evacuate
F(K)	F	Weak ankles	✓				• Heels cause her problems
G((N)	F	Weak ankle Reduced vision Cognitive	✓				• Footwear problems – especially heels • Weak ankles – keeps turning over • Multi focal glasses – difficulty in locating steps • Orientation – needs signage / landmarks
H(G)	M	DOMS in Calves Reduced vision	✓				• Damaged calf muscles downhill running when younger • Heats up quickly – fatigue – not fit • Falls on steps – difficulty locating – fall at main station

Table 6-9: Initial Comments Schedule FF1 – Individual (YOU) Core Consistency

[168] The tables of comments are inserted at this point so that they can be read in conjunction with the summary Ishikawa Chart in

Table FF 2 *YOU AND OTHERS*

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A(J)	F	Knee		✓			• Being held up by slow movers – increases stress • Crowding creating undue delays as above
B((W)	M	0		✓			• None
C(L)	M	Reduced Vision		✓			• He is slow walker embarrassed at holding others up – stresses him no end – actual fear • Scared holding up fire-fighters • Also slow mover because of vision problem
D(M)	M	Knees/ Height/large feet		✓			• Being held up initially by slow movers • Annoyed by noise and delays due to people talking in groups
E(?)	M	Not fit Arthritis		✓			• Very slow mover – stressed by not being able to keep up with group • Easily fatigued – no. of storeys due to having to keep up with group.
F(K)	F	Weak ankles		✓			• People not focussed on what they are doing and causing confusion within group / others • Could instil panic amongst group in emergency
G(N)	F	Weak ankle Reduced vision Cognitive		✓			• Embarrassed / stressed as she would hold others up – potential for fall with weak ankle
H(G)	M	DOMS in Calves Reduced vision		✓			• Crowding – having people too close so you can't see the stairs – increases risk of falling – others falling. • Also when others do not care about his problems

Table 6-10: Initial Comments Schedule FF2 – Group (YOU&OTHERS) Core Consistency

Note: Under every comment made against specific individual members there is a theme of self focus as opposed to the Content Analysis Studies. They are to do with being embarrassed as a slow mover and/or falling, tiring because of having to keep up with the group, and having vision of stairs reduced because of the presence of others. The difference is most likely because these occupants feel somewhat vulnerable due to their functional

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A(J)	F	Knee			✓		• Needs handrail to feel more confident • Signage to each level for orientation • Marking on steps for legibility
B((W)	M	0			✓		• Not wide enough between handrails • Treads too narrow • Stair design has not changed with body shape and foot size • All elements (steps/ handrails/walls) same grey colour – orientation – need to know level and direction of travel / impact on falls/ • Vital safety elements such as edge of treads and handrails should be highlighted • Must avoid 'whiteout' for reasons of the above and also if smoke penetrates stairwell • Wallpaper effect
C(L)	M	Reduced Vision			✓		• Poor edge delineation of steps – wallpaper effect • Whiteout effect where handrails and steps not marked • Where does each flight stop and start?
D(M)	M	Knees/ Height/large feet			✓		• Stairs too steep and treads too small • No variation in direction – repetitive turning – wallpaper effect compounded – dizziness • Disorientation with no signage / whiteout etc. • Very noisy – echoing from talking in groups – very intimidating will increase further with pressurisation fans and alarms • Temperature – e.g. in Adelaide was 46^{0}C
E(?)	M	Not fit Arthritis			✓		• No space provided on landings for resting • No space provided for overtaking - stairs

Table 6-11: Initial Comments Schedule FF3 – STAIRS Core Consistency

Table FF 4 ANYTHING ELSE

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A(J)	F	Knee				✓	• Crowding not going anywhere
B((W)	M	0				✓	• Nothing to add
C(L)	M	Reduced Vision				✓	• Body odour etc. and lack of ventilation etc.
D(M)	M	Knees/ Height/large feet				✓	• Time taken to get back into building when a trial • Trying to get in touch with loved ones in a real emergency on mobile phone when no reception – increased stress
E(?)	M	Not fit Arthritis				✓	• Are other systems available such as elevators?
F(K)	F	Weak ankles				✓	• Good procedures to stop excessive queuing – phased or sequential evacuation so that floors cleared in sequence and numbers within stairs kept to a minimum.
G(N)	F	Weak ankle Reduced vision Cognitive				✓	• See Stairs for overtaking lane suggestion
H(G)	M	DOMS in Calves Reduced vision				✓	• No additional comments

Table 6-12: Initial Comments Schedule FF4 for Anything Else

The comments from the above tables are summarised in the Ishikawa Chart (Figure 6-15) below:

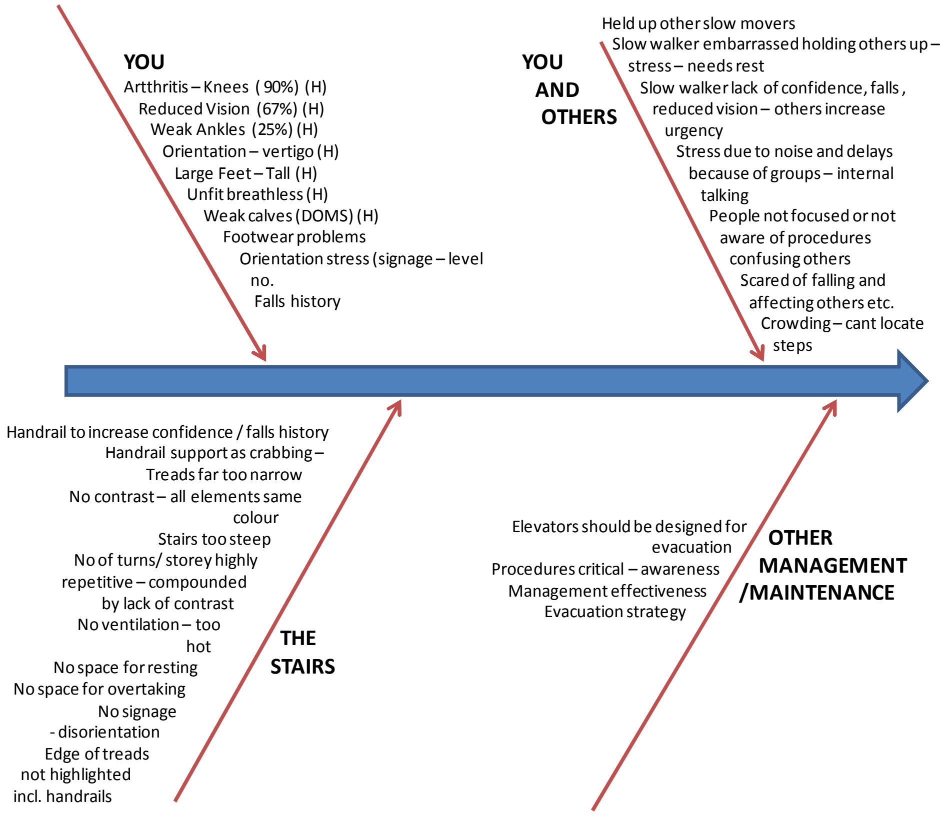


Figure 6-15: Summary of Fuller Figure Initial Comments

The Ishikawa Chart was used as the prompt for the focus group discussions. Each branch (core consistency) will now be discussed in a separate subsection. The comments from Figure 6-15 are summarised in the subsequent four subsections.

6.7.3 Individual (YOU) Core Consistency

The number of functional limitations normally associated with obese persons was mentioned as arthritis (knees), weak ankles, dyspnoea, and falls. Fitness was also mentioned. This is not a comprehensive list by any means when compared with those summarised in Chapter 2 from Booth et al (2002). The three female members all have waist measurements of 900mm+ and five out of the six males had waist measurements over 1000mm. This is seen to be a more reliable measure of fitness (Yancey et al, 2008) as the waist is where adipose tissue is normally distributed. The measurements show a group where the waist circumferences coincide with the recorded BMI. Note the majority of Questionnaire responses completed separately from the focus group session add cardio-vascular conditions and unspecified mobility issues most likely linked to the participant's BMI of 40, waist measurement of 1200mm and fatigue. This participant mentioned that she could only cope with 20 floors. Falls history is shown but this also includes fear of falling applying to four out of the nine members. Vertigo and dizziness were mentioned during discussion and the members concerned linked this to their fear of falling.

The "rich view" of the stairwell void was mentioned by the members reporting the vertigo and dizziness problems. One of these participants mentioned that she could only cope with a total of 10 storeys. Muscle fatigue associated with the lower legs was mentioned for a few of the participants but not considered a major limitation. The details are summarised against the participants concerned in Table 6-13. None of the group members reported problems with hypertension such as those persons reported on by Shields et al (2009) which is quite often associated with obesity (Booth et al, 2002).

Fuller figure focus group with some functional limitations and possibly not fit
Individual characteristics and storeys coped.

Participant No.	Name	Gender	m/sec.	Age	Height	Mass	Waist	BMI	Shoe Size	Storeys Coped	Adj st descent	
1	NA	Female	0.41	32	1520	90	1200	40	5.5	32	0.41	
2	NA	Male	0.37	41	1680	96	1170	34	11	20	0.37	
3	NA	Male	0.41	47	1920	124	1250	34	10.5	20	0.41	
4	NA	Male								*		
5	NA	Male	0.40	50	1750	96	940	31	10	32	0.40	
6	NA	Female	0.35	32	1600	73	900	29	8	32	0.35	
7	NA	Male	0.29	45	1780	113	1150	36	9	10	0.29	**min**
8	NA	Female	0.42	38	1650	95	950	35	7	20	0.42	**max**
9	NA	Male	0.28	62	1791	122.7	1200	38	9	20	0.28	
10	NA	Male	0.33	52	1800	108	1090	33	12	18	0.33	
	**included in Mature age focus group*										0.36	**mean**
	Female participant suffers from Graves disease - saps strength - risk of falling;											
	Male indicates fear of falling after 10 floors - reduced mobility condition											
	Participant 10 has reduced vision and problems with depth of field perception / foot placement											

Table 6-13: Fuller Figure Descent Speeds and Individual Characteristics

In order to provide guidance for the interpretation of the results from the surveys and observation associated with buildings M1-M6 in Case Study 2008-

2010 and also the Aim of the PhD Study stair user performance should be related significantly to waist circumference. The actual level of significance is only moderate ($p<.05$) and $R^2 = .21$ for a polynomial relationship ($y= 0.383x^2 + 10.232x + 1079.7$) where y is the waist circumference in millimetres and x is the number of storeys.

The impact of distance travelled using the BMI Benchmark trend lines will be discussed in a subsequent section where the outcomes of the two focus groups are compared.

6.7.4 The Group (YOU & OTHERS) Core Consistency

The note below follows under Table 6-10:

"Under every comment made against specific individual members there is a theme of self focus as opposed to the Content Analysis Studies. They are to do with being embarrassed as a slow mover and/or falling, tiring because of having to keep up with the group, and having vision of stairs reduced because of the presence of others. The difference is most likely because these occupants feel somewhat vulnerable due to their functional limitations."

The members of the group focus on themselves as compared with those mentioned in Content Analysis Studies One and Two. In doing so, they provide some valuable answers to the Research Questions mentioned in Chapter 1 dealing with group compliance. The members' concern was that as slow movers they were embarrassed (50% of the group members). The comments were that, in attempting to travel at a faster speed than they are comfortable with, they tire more easily and increase their risk and fear of falling[169]. These members were obese and studies show that this condition also interferes with balance (Al-

[169] This finding is extremely significant and is used to explain results of surveys of occupants of buildings M1-M6 In Chapter 7

Abdulwahab, 1999). Another vital issue is the impact of others in obscuring the steps and increasing the risk of falling for others.

There is also concern based on previous trial evacuation experience that not all the members in the group are concerned about others in the group. Here is an example of partial agreement with the NY Times Blog Study where non-altruistic behavioural attitudes were present even although this was less than 8% of the responses. Intergroup influences due to the lack of familiarity with procedures or focus caused confusion between groups on the stairs. There is no information here for the impact of the group on descent speeds where other studies in progress show the impact internal group communications can cause the same degree of slowing as tiring (MacLennan, 2011a) and/or delay.

6.7.5 The “STAIRS” Core Consistency

This section analyses the results presented in Table 6-11

Foot placement is the first issue as one of the members wears a size UK12 whilst four out of the nine members wear a shoe size greater than UK9. The resultant toe overhang would have been greater than 40mm. Four out of the five participants confirmed their concern with the width of the treads (260mm).

They mentioned that another problem with foot placement was the legibility of the steps and the landings. The lack of contrast between surfaces and handrails hampered their orientation, locating the handrails for support and locating the steps. This could heighten the fear of falling in a group who were already predisposed that way. Reduced vision was also associated with foot placement because of problems with depth perception.

The width of the stairs suggested by other studies as a critical factor (Peacock et al, 2009 and Pauls et al, 2007) was found to concern four out the eight group members. The concern was to allow others to overtake and to provide a place for resting.

The most significant collection of comments concerned the constant "downward spiral" and that this is exacerbated by the number of turns per storey, the width of the void and the lack of contrast between surfaces. It was the group's unanimous opinion, given their predisposition to falling, that this problem should be and could be remedied by Management. A single handrail also did not help as not everyone could reach it. Signposting as to levels, providing contrasting surfaces, marking the edges of each step and adding contrasting handrails are all examples of improvements.

6.7.6 Management and Maintenance Core Consistency

This core consistency was noted under "Anything Else" by most members of the group. In doing so they emphasised the importance of the procedures. Other significant responses were:

- Good maintenance to provide adequate ventilation and illumination.
- Those who are not suited to stairs should use elevators especially when there is a tried and tested procedure in place that is frequently practised with the Fire Service.
- Have a strategy that avoids excessive queuing and the associated stress such as sequential evacuation. This comment was made even with the concern with the resultant faster descent speeds (keeping up with the group).
- Widen the stairs and include an "overtaking" lane. Comment only made by one member and not taken up by others

The issue of occupant suitability for stair use was raised in this focus group as it was in the Content Analysis Studies. Maintenance in terms of adequate ventilation and illumination was also consistent with the Exploratory Case Study in Chapter 5.

6.8 Mature Age Focus Group Study

The main 2008-2010 Case Study shows that age does not correlate significantly with fitness/ obesity and other functional limitations. This Focus Group Study will be used to place this finding in context and even help to clarify it. Also consult Table 6-19 and Figure 6-17 for this entire section for comparison with the Fuller Figure Focus Group results.

6.8.1 Results - Initial Comment Schedules

The initial comments coded from the mature office worker (MOW) sessions are presented in Table 6- 14 to Table 6-17[170] below:

Participant No.	Gender	Condition (Coded)	Element YOU	You/ Others	Stairs	Any/ else	Comment
A (P)	M	Sore Knees Vision	✓				• Sore knees that would cause problems with > 32 storeys
B(Male 1)	M	None stated	✓				• Very slow walker – scared / stressor – he will hold others up. • Reliant on handrail
C(Woman1)	F	Vertigo Sore right knee (arthritis)	✓				• Hates to be held up as her knee seizes up • Walking behind people in loose footwear e.g. 'flip-flops' or thongs as she is scared of stepping on them • Wearing loose shoes herself scared of falling • Falling due to vertigo e.g. large stairwell opening.
D(Woman2)	F	Falling history Vestibular problem	✓				• Has a vestibular condition (not elaborated) so that she has an inordinate fear of falling • Always holds on to handrail
E(Male 2)	M	Damaged calf muscles	✓				• Legs very sore so that no of storeys that he can cope with will be affected • Very unfit due to lifestyle and condition – 15 floors limit. • Needs to practice
F(Male 3)	M	Poor Vision Damaged Leg	✓				• Poor vision even with glasses • Soreness in leg • Constant turning causes problems
G(Male 4)		Poor Vision	✓				• Poor vision – multi focals with tinted lenses that cause problems with depth perception and locating of steps

Table 6- 14: Initial Comments Schedule MOW 1 – The Individual (YOU) Core Consistency

170 These tables are inserted at this point to be read with the summary Ishikawa Chart in Figure 6-16

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (P)	M	Sore Knees Vision		✓			• Marked fear of crowds in terms of others falling and causing him to fall as well of pressure being required to help • Seeing steps blocked by others.
B(Male 1)	M	None stated		✓			• Scared of holding others up and impact of fast descent on his ability • Queuing delays • Potential of crowds for panic/ confusion
C(Woman1)	F	Vertigo Sore right knee (arthritis)		✓			• Hates to be held up – knee seizes • Others with flip flops or thongs – footwear – increased risk of falling and also one must be careful not to step on loose heel.- falling
D(Woman2)	F	Falling history Vestibular problem		✓			• No relevant comments re this element
E(Male 2)	M	Damaged calf muscles		✓			• No relevant comments re this element
F(Male 3)	M	Poor Vision Damaged leg		✓			• Noise in the stairs due to incessant chatting between members of groups
G(Male 4)		Poor Vision		✓			• Crowds reduce reflectance of surface and clarity of steps making location of steps difficult – caused him to treat as a hazard

Table 6-15: Initial Comments Schedule MOW 2 – Group (YOU & OTHERS) Core Consistency.

Note: Under every comment made against specific individual members there is a theme of self focus as opposed to the Content Analysis Studies. They are to do with being embarrassed as a slow mover and/or falling, tiring because of having to keep up with the group, and having vision of stairs reduced because of the presence of others. The difference is most likely because these occupants feel somewhat vulnerable due to their functional limitations.

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (P)	M	Sore Knees Vision			✓		• Treads too narrow – others falling • Amount of turns with monotonous/ whiteout environment • Need two handrails and wider stairs • Highlight nosings and handrails to reduce wallpaper effect • Lack of ventilation and temperature • Organise procedures so that internal accessible third stair can be used • Large numbers on walls for orientation especially when fire doors are missing as these act as landmarks for each level
B(Male 1)	M	None stated			✓		• Tight number of turns so that need to use handrail for stability to overcome dizzy feeling • Temperature in stairs and lack of ventilation
C(Woman1)	F	Vertigo Sore right knee (arthritis)			✓		• No relevant comments re this element
D(Woman2)	F	Falling history Vestibular problem			✓		• Reduced lighting – difficulty finding steps – really serious fear of falling • Holds handrail to counteract fear of falling
E(Male 2)	M	Damaged calf muscles			✓		• 15 floors can be problem
F(Male 3)	M	Poor Vision Damaged leg			✓		• Constant turning is annoying and affects leg • Noise in stairs due to others in stairs • Trials do not reflect emergencies
G(Male 4)		Poor Vision			✓		• Lack of lighting affects especially with tinted glasses so also uses handrail for stability

Table 6-16: Initial Comments Schedule MOW 3 – STAIRS Core Consistency

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (P)	M	Sore Knees Vision				✓	• Change procedures so that accessible stairs can be used – fire stairs should have accessible standards
B(Male 1)	M	None stated				✓	• There is a potential for panic
C(Woman1)	F	Vertigo Sore right knee (arthritis)				✓	• Procedures on footwear in stairs
D(Woman2)	F	Falling history Vestibular problem				✓	• Lighting maintenance must be high
E(Male 2)	M	Damaged calf muscles				✓	• Procedures for those with conditions that will increase falls potential • Must practice more •
F(Male 3)	M	Poor Vision Damaged leg				✓	• Trial needs to reflect emergency conditions more
G(Male 4)		Poor Vision				✓	• Lighting must be highly maintained - critical

Table 6-17: Initial Comments Schedule MOW 4 (Anything Else)

The outcome of Table 6- 14 to Table 6-17 is summarised in the Ishikawa Chart below:

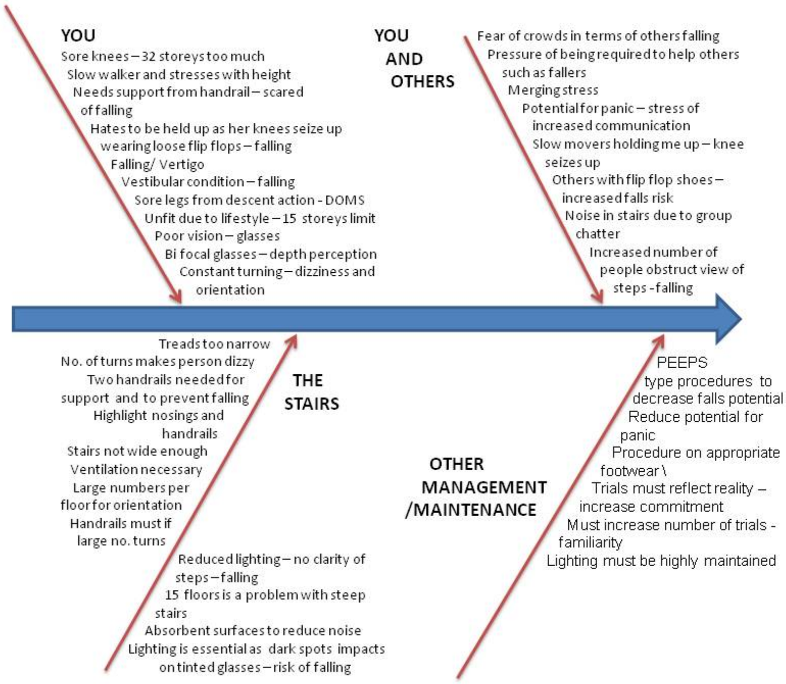


Figure 6-16: Summary of Mature Age Comments

The Core Consistency on each of the branches in the above Chart (Figure 6-16) will be analysed in the next four subsections. The functional limitations and associated descent speeds are shown in Table 6-18. The range of descent speeds will be compared with other studies in a subsequent section as the comments from this group about travelling at a fast speed increasing the fear and risk of falling is similar to those from the Fuller Figure focus group.

Mature Age Focus Group > 45 years
Individual characteristics and storeys coped.

Participant No.	Name	Gender	m/sec.	Age	Height	Mass	Waist	BMI	Shoe Size	Storeys Coped	Adj St Desc Spd.	
1	NA	Male	0.36	53	1752	60	800	20	8	30+	0.36	max
2	NA	Male	0.34	61	1854	108	1150	32	10.5	15	0.34	
3	NA	Male	0.35	59	1700	105	1020	36	8	16	0.35	
4	NA	Male	0.28	63	1800	118	1200	36	9	20	0.28	min
5	NA	Male	0.34	50	1750	96	940	31	10	32	0.34	
6	NA	Female	0.32	56	1626	70	750	26	7.5	19	0.32	
7	NA	Male	0.34	52	1840	86	910	25	9	40	0.34	
8	NA	Female	0.30	58	1676	62	762	22	6.5	25	0.30	
	Participants 4 and 5 indicated fear of falling and participant 4 reported actual incident of trial evac fall										0.33	mean

Table 6-18: Mature Age - Descent Speeds and Functional Limitations

(*R^2=0.378 with a moderate level of significance <.05 where there is a polynomial relationship as before.)*

Although the relationship between waist circumference and estimated stair descent capability is only moderately significant it is supported by the reduced descent speed (compared with minimum of 0.6m/sec for the BMI Benchmark Group) and enhanced by the comments.

6.8.2 The Individual (You) Core Consistency

The conditions recorded from the survey for this group include vertigo / dizziness, balance disorder, arthritis in the knees, fitness, cardio-vascular condition, reduced vision (depth perception), footwear issues, orientation issues, and five out of the eight members have a fear of falling. The latter is very much exacerbated by the illusions created by the width of the void and the repetitive downwards spiralling movement compounded by the number of turns (similar to the Fuller Figure Group). The impact of these conditions is confirmed in Table 6-18 following their anticipated reaction to the stairs from previous trial evacuations.

Three out of the six male members had a waist circumference over 1000mm and one with a circumference of 1200mm. This male person also recorded the slowest descent speed and could cope with the least number of storeys and fell during the actual trial. The incident involved the person coming to rest on the ground satisfying the definition of a fall by Tinetti et al (1988). This person also reported that the maximum number of storeys they could cope with was 20. The maximum descent speed was 0.36m/sec, the mean 0.33m/sec and the minimum 0.28m/sec. In attempting to develop a suitable measure of occupant stair performance, which underpins the Aim of the PhD Study, waist circumference can only predict 38% of the variance of the estimates that members make of the number of storeys they think they can cope with. This is a slightly stronger relationship than for the Fuller Figure Group (see Table 6-13) but it is still only moderately significant ($p<.05$).

ELEMENT	PARTICIPANT NUMBERS																	
	MA1	MA2	MA3	MA4	MA5	MA6	MA7	MA8	FF1	FF2	FF3	FF4	FF5	FF6	FF7	FF8	FF9	FF10
Health Condition	none	arthritis/knees	heart/vision	arthritis/knees	heart/arthritis	injury/dizzy#	vertigo##	dizzy*	mobility***	none	heart		asthma/arthritis	strength	balance/mobility^		diabetes etc.	gait impair
No. Falls	one	none	none	one**	none	none	none	none	none	none	none		none	none	none		three	3###
Handrail easy	1	1	2	4	1	1	1	1	1	1	1		1	1	1		5	1
Step legibility	1	1	2	4	1	1	2	1	1	1	1		1	1	1		4	5
Too steep	5	5	1	4	2	2	2	4	4	2	2		2	4	4		1	4
Narrow treads	5*	5*	4	4	2	4	2	4*	4	2*	1*		1	4	4		1	4
too many flights	5	4	2	1	4	4	4	2	4	5	1		2	5	2		1	2
Lower limb discomfort	1	2	2	1	2	1	2	1	2	4	1		2	2	1		1	2
Fear of falling	5	4	2	1	2	4#	2##	2*	4	5	2		2	5	4		1	2###
Dyspnoea	2	2	2	1	4	4	2	2	2	5	1		2	5	1		1	2
Chest discomfort	4	5	4	3	4	4	4	4	4	4	2		4	5	4		1	4
Fatigue	5	2	2	2	2	4	1	1	2	2	1		2	2	1		1	2

** Participant MA1 had size 8 shoes and would have been able tp place foot on the tread; Participant MA2 had 10.5 shoes and would not have been able to face front on. MA8 as per MA1 as further example.*

**FF2 has size 11 shoes & could not face front on. FF3 has a shoe size of 10.5 and would have problems facing front on with a waist measurement of 1200mm. FF5 has a shoe size of 10..*

** *Participant MA3 fell during an actual trial evacuation*

***#P** articipant MA 6 has problems with her balance after 20 floors based on previous trials*

Participant MA7 still plays some sport but suffers from vertigo and reacted to the wide well

**** This participant has a BMI of 40 and can only cope with 20 floors. She has a 6.5 shoe size and can face front when going down the stairs*

^ FF7 can only cope with 10 storeys - implying balance problems thereafter - not fit or strength problems

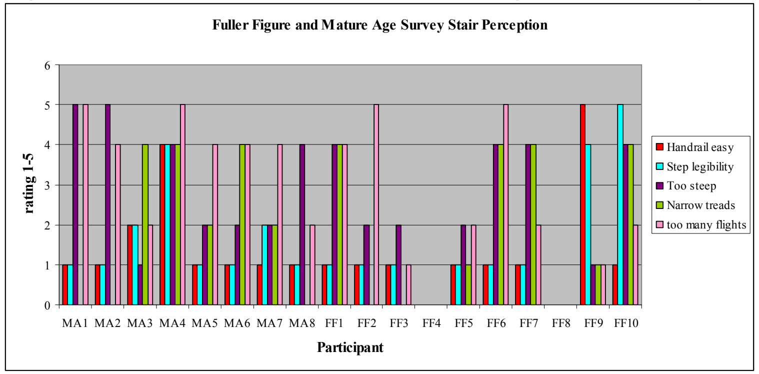
FF10 has severe problems with stepping and depth perception/ foot placement

(yellow)	*FF4 transferred to the Mature Age Focus Group*
(olive)	*FF8 did not complete a questionnaire*

LEGEND AND NOTES

Table 6-19: Fuller Figure and Mature Age Survey Data

Figure 6-17: Vertical Bar Chart of Mature Age and Fuller Figure Perceptions



6.8.3 The Group (You and Others) Core Consistency

There was some difference to the response from the Fuller Figure Group mainly concerning embarrassment in slowing down a group. This concern was mirrored in a fear of crowds and holding up the group. They were concerned that had to go down at a faster pace than they were comfortable with. Members did complain about others in the group obstructing their view of the steps and that this added to their fear of falling. The net outcome is still the same as the Fuller Figure Group.

Noise of chatter between members of other groups disrupted their focus. This noise could also cause confusion when it was legible and showed that the other groups did not know what they had to do.

There was a mention made of the footwear of other members especially when the footwear was loose fitting. Sometimes being in close proximity to others could result in a fall if the loose footwear was detached from the foot of the person in front. This comment was not taken up by other members in the group.

Otherwise the findings are similar to the Fuller Figure Group.

6.8.4 The STAIRS Core Consistency

Treads were found to be too narrow by two out of the eight of the members. This concern only corresponded with a shoe size being in excess of UK9 in one instance. Three out of the eight members thought that 37^0 was too steep for a set of stairs. When steep stairs are coupled with the wide void, the continuous downwards spiral and the lack of contrast between surfaces and legibility of steps it creates an environment that triggers fear of falling. When others obstruct the view of the steps this makes the problem even worse.

Constant turning (4 times a storey) can cause severe pain in a person's knees, quadriceps and hips. This replicated the concern of the "downward spiral" presented in the previous main section.

Members mentioned reduced lighting as an issue which increases the problems with the lack of legibility of the steps. They also mentioned that lack of ventilation can increase temperatures because of lack of air movement causing a person, and others, to sweat, resulting in slippery handrails.

A significant comment was made concerning the minimum width of stairs. The members maintained that the stairs should be wider providing places for rest. An additional handrail could then also be added as they were adamant that a single handrail was not enough.

The other issues are identical to those for the Fuller Figure Group.

6.8.5 Management and Maintenance Core Consistency.

Maintenance was seen as being one of the main issues in the areas of lighting and ventilation. This reflected similar significant findings from the 1977 Canadian Study (Beck, 1977) which were found to be moderately significant ($p<.05$).

Members stressed the importance of evacuation procedures to reduce the risk of falling which agrees with the findings from the Exploratory Case Study in Chapter 5. The number of trials needs to be increased so that whatever is put in place to cater for the needs of the older workers and other persons with the associated functional limitations can be properly trialled and catered for. PEEPS[44] (DCLG, 2007a) was discussed as being a good way forward.

Members were concerned about the level of commitment of other participants in trial evacuations. Lack of commitment they maintained results in confusion and stress amongst those who want to take part, putting others at risk.

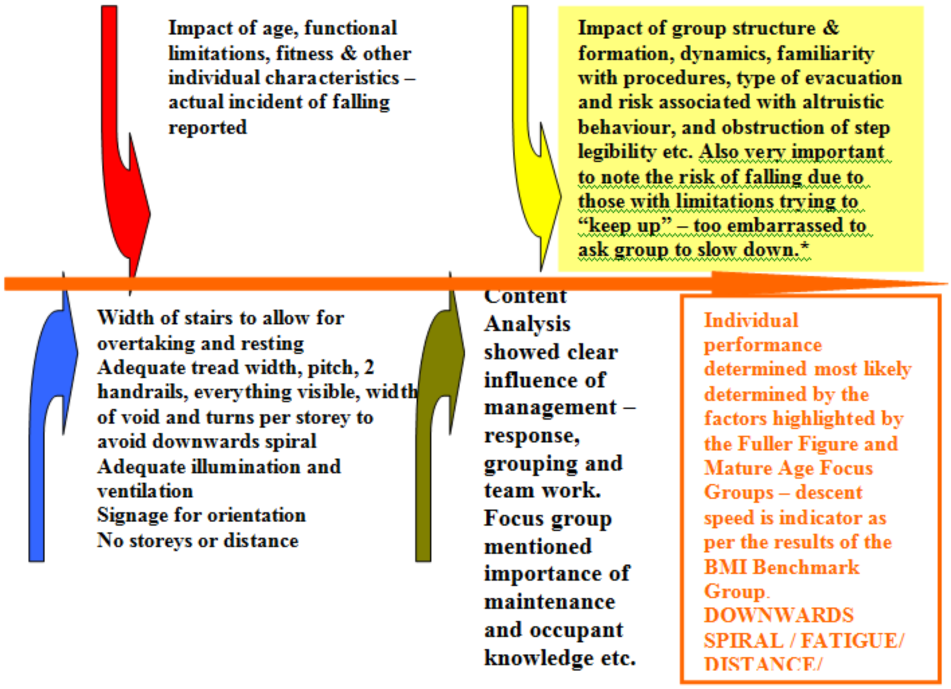
Other issues raised are similar to those raised by the Fuller Figure Group.

6.9 Discussion of Results from BMI and Focus Group Studies 1 and 2.

6.9.1 Overview

The BMI Benchmark Focus Group represents relatively young office workers. Their exercise profile may have matched that mentioned by Steele and Mummery (2003) but the results showed that 8 out of the 10 participants participated in a vigorous leisure-time exercise programme. The results show two participants with a functional limitation (asthma and reduced vision) had minimum descent speeds and that overall the descent rate slowed as a function of the number of storeys. The mean descent speeds from the Fuller Figure and Mature Age Focus Groups were then adjusted using the Benchmark trend. Using the Christchurch trend the mean descent speed reduced to a speed at the bottom of the stairs equal to the measured minimum of all the participants. The same did not apply using the Sydney trend line. This may demonstrate that as the number of storeys increases so does the reduction in descent speed.

Distance is shown by Peacock et al (2009) to be a predictor of descent speed down multiple flights of stairs and this is further supported by health science studies (Reeves et al, 2008: Leake et al, 1991; Hulens et al, 2003 and Fritz, 2009). The UK Delphi Sub Group advised the author to use descent speed as a measure of fatigue or impact of functional limitations in line with Fritz (2009). Spearpoint and MacLennan (2012) also related functional limitations and/or capacity to evacuation performance.



* *Focus Group response differs from Content Review Studies – Participants commented on impact of the Group on their individual performance both positively and negatively (e.g. embarrassed and fearful of being "forced" to go down the stairs at a faster rate than they felt confident with; this heightened their fear of falling).*

Figure 6-18: Ishikawa Model Summary for Discussion of Focus Group Results

The relevance of distance will also be shown in the results of the main 2008-2010 Case Study in Chapter 7. Advice from the UK Delphi Sub Group is extremely relevant including the most significant finding from the Focus Group Studies is where individuals who are morbidly obese and/or have some functional limitations are more fearful of falling when they travel at an uncomfortable speed to fit in with their group. They do so either from embarrassment or their fear of others (crowds). Focus Group descent speeds can then be compared with the actual descent speed of the group to identify the percentage of individuals who are at risk of falling.

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***

Table 6-20: Comparison of Stair Descent Speeds

(Represents mean descent speeds measured across a group and do not reflect slowing down due to distance traversed)

6.9.2 The Individual (You) Core Consistency

Chapter 2 shows the impact of health conditions, age and fatigue on individual descent performance (Ayis et al, 2007). Rheumatics, cardiovascular conditions, dyspnoea, reduced vision results in mean descent speeds of 0.2 – 0.25m/s. Increases in age from 36 to 66 years results in descent speeds of between 0.35m/s and 0.26m/s. Based on the six minute walking test, Fritz (2009) and Ayis et al (2007) show the impact of fatigue relates directly to distance with speeds varying from 0.35m/s to 0.2m/s. Similar results are available for increased obesity (Stenholm et al, 2008; Fjelstad et al, 2008; and Browning and Kram, 2007) which also impact on balance and posture (Corbeil et al, 2001; Menegoni et al, 2009 and Teasdale et al, 2007) making people more cautious going down stairs or negotiating irregular terrain. This then supports the results shown in the Focus Group Studies as well as those of the BMI Benchmark Group for a reduction in walking speed related to distance traversed.

Table 6-20 shows that the Fuller Figure and Mature Age Focus Group results compare favourably with other studies where participants had functional limitations (Boyce et al, 1999; Jiang et al, 2012 and Proulx et al, 2007). The BMI Benchmark results compare favourably with those of Peacock et al (2009) which involved trial evacuations in 6 – 18 storey office buildings in terms of the maximum descent speeds. BMI Benchmark Group participants descended the stairs on their own at set intervals. The maximum descent speed in the Sydney BMI Benchmark Sub Group was a speed achieved over a short distance. The reduction in descent speeds for those with functional limitations also lines up to a reasonable degree with the work of the health science studies (Al-Abdulwahab, 1999; Ayis et al, 2007; and Hulens et al, 2003). It is interesting to note that the only challenge to this statement may be from Shields et al (2009) but the persons they analysed with self designated functional limitations did include hypertension. When these findings are viewed in the context of Comment 102.65 from the 102 Minutes Content Analysis a variance appears. It may quite well be that the participants were mentally much stronger or did not have as much pain. Morbid obesity coupled with dyspnoea and arthritis can deliver this type of result (Booth et al, 2002). Morbid obesity, a characteristic of over 50% of the Fuller Figure Focus Group, needs to be related to the strong connection that exists between obesity related conditions such as hypertension and diabetes and actual falls as demonstrated by Fjelstad et al (2008) in Table 6-21. Falls if taken as a function of distance traversed was discussed by the Fuller Figure and Mature

Age Focus Groups. They complained about the continuous "downwards spiral" of the stairs coupled with the repetitive turning at each landing. This complaint is associated with the psychological status of the individual (Lord et al, 2007) and correlates strongly with reduced descent speed as presented in the results in Table 6-20. An incident of falling in a trial evacuation was recorded for the Mature Age Group[171]. The functional limitations here were a combination of lack of strength, obesity, reduced vision and fear of falling. Reduced vision related to contrast sensitivity and depth perception, all of which were mentioned, triangulate well with the actual conditions being lack of contrast between surfaces and edge definition of the nosings. The latter is well supported in the literature in relation to stability and falls (Tiedemann et al, 2007; Startzell et al, 2000 and Buckley et al, 2005).

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Condition	**Obese (N= 128)** *Mean mass = 100.5Kg / Mean BMI = 35Kg/m2*	**Non Obese: (N= 88)** *Mean mass = 63.5Kg/ Mean BMI = 22.8Kg/m2*
Hypertension	51% *(2.2X)**	23
Diabetes	13 *(2.9X)**	4.5
Hyperlipidaemia	48 *(1.5X)**	31
Fall history	27 *(1.9X)**	15

Table 6-21: Subject characteristics in Fjelstad et al (2008) Study. * Indicates factor by which the condition is prevalent in the obese group as compared with **the** non-obese

The inclusion of the BMI Benchmark Group Study as a "control" for the studies in this Chapter is also proven as it corresponds with other studies. All the focus group studies incorporated the IPAQ standard questionnaire so that reliable levels of fitness were recorded as well.

[171] This incident was recorded in one of the building's standard trial evacuation exercises that did not form part of this study as it was held at another time.

6.9.3 Group (You and Others) Core Consistency

As previously explained the rate and pattern of group formation was not raised in the Focus Group Studies. The members of the Focus Groups were concerned about their own relationships with others. Those Focus Group members who classified themselves as slow movers were concerned to the point of being "scared" of holding up other group members. They did not feel comfortable "keeping up" with other group members as they thought they might fall. This concern can be justified where the individual functional limitations lead to falls (Tiedemann et al, 2007 and Fjelstad et al, 2008) as shown in Table 6-21.

Some Focus Group participants stated that they were afraid of crowds in terms of others falling, confusing actions and most of all not be able to see the steps. When this is linked with reduced vision (contrast sensitivity and depth perception) (Buckley et al, 2005) then this will disrupt gait and overall stability.

Another interesting similarity was in the area of familiarity of groups with evacuation procedures. The concern that some Focus Group participants had with the impact of the confused actions and behaviour of "other groups" is that it can cause stress. Trial evacuation practice is therefore extremely important (Gershon et al, 2008a). The "other group" perception is interesting when the Exploratory Case Study shows that more than 80% of the respondents knew the others they could see in the stairs which means that the "other groups" could have actually been an affiliate group (Shields et al, 2009).

The "slow mover" consideration for older and obese office workers may therefore be critical when viewed as possibly increasing the falls risk (Lord et al, 2007) and also the increased burden placed on group members to assist when they may not be skilled enough to do so. Wider stairs with places to rest may be an answer. This is a concern for Management and places an additional responsibility on them to keep the stairs clean and free from obstructions which was a reasonably significant finding in the 1977 Canadian Study (Beck, 1977, $p<.01$). This question is a research question and needs to be further analysed in the 2008-2010 Case Study.

6.9.4 The STAIRS Core Consistency

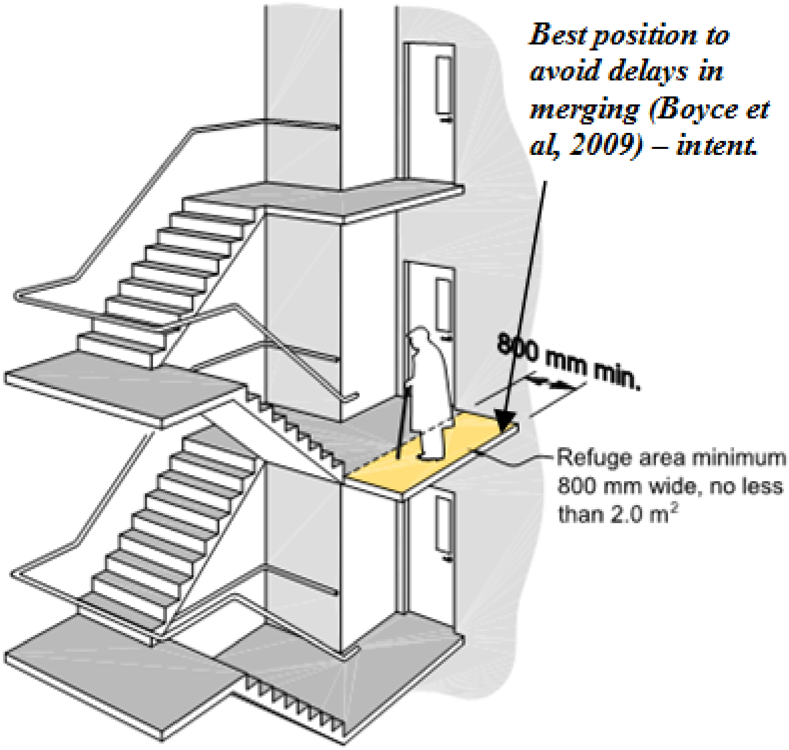

Figure 6-19: Simple form of refuge

The major similarity across all the Studies in Chapter 6 is the concern about the width of the stairs. The concern is not necessarily the same as that determined by Peacock et al (2009) or Pauls et al (2007) which is based either on counter-flow or providing overtaking potential but rather on room for the provision of unfettered assistance and also for resting. A possible answer that addresses the needs of all is that shown in Figure 6-19.

The STAIR Core Consistency was the least predominant in the Content Analysis Studies. The main category was width of stairs. The other categories recorded against this Core Consistency in the Content Analysis Studies that can be supported as being vital (Archea et al, 1979; Templer, 1992; Startzell et al, 2000; and Roys, 2006) were:

- Narrow treads - confirmed as critical (Roys, 2006)

- Handrails – not really mentioned in the Content Analysis Studies (5.9%) but extremely important to the Focus Groups even if just to provide assurance (Reeves et al, 2008a)

- Ventilation conditions – significant ($p<.05$) in Canadian Study (Beck, 1977).

- Lighting - significant ($p<.05$) in Canadian Study (Beck, 1977).

The Focus Groups did mention all of the above factors but added step legibility, contrast of surroundings and signage for orientation, reachable handrails, and the problem of the "downward spiral" exacerbated by the rich views through the wide void (Archea et al, 1979 and Templer, 1992) and the number of turns per storey. These two elements were seen to promote falling via repetitive action in terms of vertigo, dizziness and providing an unnecessary distraction impacting on the individual's degree of focus. This can also be supported by the reduction of stair visibility and the resultant interaction with the individual's sensory system resources (Horak, 2006).

The Focus Groups talked about the lack of contrast as creating conditions similar to a "white-out" as being critical as it interferes with orientation, depth perception and stability and is supported by Alderson (2010) and Startzell (2000). They also mentioned the frustration caused by others in this type of environment as these others obstructed the view of the steps. Marking the stair nosings in a contrasting colour is extremely important according to the Focus Groups in addressing the above problem. Step legibility is supported by Alderson (2010) as well as being a requirement for "Accessible Stairs" in most Codes such as AS1428.1-2009 (Standards Australia, 2009).

6.9.5 Management and Maintenance Core Consistency

The Ishikawa Chart in Figure 6-18 summarises the issues raised by the focus groups that were finally coded to this core consistency. These are discussed in greater detail as follows:

- Commitment to, understanding of and practicing of evacuation procedures so that all individuals know what they are doing. This is supported by Gershon et al (2008a).
- Allowing for sequential evacuation so as to avoid delays due to merging, and "platooning" (Templer 1992) due to multiple slow movers.
- Group formation inferred as being loose in terms of the number of people that Focus Groups knew in the stairs at any one time (as per the Exploratory Case Study and the "affiliate group" (Shields et al, 2009)) so that negative comments made about confusing behaviour associated with noncompliance with the first bullet point can be placed in context.
- Group formation practice being voluntary or part of the evacuation procedures.
- Maintenance in terms of ventilation and lighting. Cleanliness and removal of rubbish was not mentioned as it was in the Exploratory Case Study mainly because of the constant clean state of the M6 Building Stairs. The latter was the reference point for the two Focus Groups.

Gershon et al (2008a) mention the importance of preparedness which underpins the first bullet point. The 102 Minutes Content Analysis showed the impact of JP Morgan, a major tenant and employer of over 2000 individuals in the WTC "Complex" at the time of the 9/11 Incident, can have on the orderly and informed behaviour of evacuees. This firm were totally committed to their employees and therefore were fully prepared and practised (Dwyer and Flynn, 2004).

A dichotomy exists with the second bullet point. Both sets of studies indirectly showed the importance of group size and structure. The dichotomy is in terms of group dynamics (member behaviour). Where the member has functional limitations that reduce their descent speed the discussions were concerned with keeping up with the group which would descend faster in a planned sequential evacuation than they would in an uncontrolled evacuation. The net outcome would be an increase in the risk of falling because even with a misstep the individual may not be able to recover due to fatigue or loss of strength (Al-Abdulwahab, 1999 and Lauretani et al, 2003).

The interaction of this core consistency with all of the others therefore plays an important part in the functional capacity (Matheson, 2003) of the occupant or individual to safely descend a predetermined number of flights of stairs. The functional capacity needs to match the estimated capacity so that PEEPS[44] is the vehicle that Management and the occupant or individual need to work on to make this happen.

6.10 Summary of the Findings from Chapters 5 and 6

The results are summarised from Chapters 5 and 6 for each of the Core Consistencies in 6.10.1: Table 6-22 to 6.10.4: Table 6-25.

6.10.1: Table 6-22: The Individual Core Consistency[172]

Category or Detailed Factor	Exploratory Case Study Buildings 3 and 7	Content Analysis Study	Focus Groups	Integrated Result (For comparison with 2008-2010 Case Study Results
Age	Not available but 20% of 45+ (Rowland 1991)	Not available but mentioned	Provided	Age
Gender	Not available in SPSS V2.1 Hardcopy but originally measured	Not available but mentioned	Provided but did not appear significant (see also Peacock et al (2009)	Gender
BMI / Waist circumference	Not available in SPSS V2.1 Hardcopy but originally measured	Mentioned in generic terms e,g heavy, obese etc.	Provided and significant	BMI/ Waist Circumference
Functional Limitations				
	Arthritis, cardio-vascular, balance incl. vertigo and dizziness, fear of falling, proprioceptive ability in terms of foot placement, fear of falling, and falls history.	Included as health condition – predominant detailed factor or category including obesity, asthma, arthritis, cardio-vascular etc. in comments.	Reduced vision, arthritis, depth perception, asthma, weak ankles, reduced strength, orientation ability, impaired gait, vertigo and dizziness, balance and needs support, fear of falling and falls history, fear of others and embarrassment over limitations	Arthritis, osteoarthritis, rheumatic problems, other lower limb musculo-skeletal problems, impaired vision and associated neurological issues, asthma, cardio vascular/ respiratory issues, orientation ability, impaired gait, proprioceptive ability, stance and gait issues, vestibular conditions incl. vertigo, dizziness, stability and balance, fear of falling, reduced strength especially lower limbs. Fear of others is also a factor in terms of the visibility of the steps.
Fatigue	Mentioned in data and significant relationship with maximum individual perceived performance	Comments such as 102.24 and 102.65 show impact of fatigue	Fatigue was mentioned and linked in with the downward spiral movement cycle	Fatigue is measured using self reporting technique. It is underpinned by strength and linked to distance or effort. As such there is a direct link to fitness and exercise which can be measured reliably by a validated self reporting technique (Sjostrom et al, 2005)
Fitness	Mentioned in data	Mentioned mainly in the NY Times Blog Study and related to obesity and slow movers.	Not directly mentioned but recorded via survey using a reliable technique (Sjostrom et al, 2005)	Fitness is crucial as it is related to strength and endurance capacity. Lack of fitness and the resultant reduction in strength increases the risk of falling. The individual's level of physical activity is therefore critical and forms part of the validated fitness self-reporting tool (Sjostrom et al, 2005)

6.10.1: Table 6-22 shows the integrated result of the intrinsic factors from the Exploratory case study, the Content Analysis Studies and the Focus Groups. Columns 1-3 list the individual results. Age and gender were only provided exclusively in the Focus Group studies but do need to be considered as an issue from Chapter 2. BMI was measured in the Exploratory case study but hard copy details were not available other than for information from the explanatory Canadian Study (Beck 1977) relating to fitness. BMI and waist circumference were found to be factors in the Focus Group studies and therefore have been included. Fatigue is the one factor that was in common for all studies except that some of the research on the WTC 9/11 incident did not find it to be an issue (Galea et al, 2011). This constitutes a "rival theory" (Yin, 2009) and can be

[172] Functional limitations are highlighted as they represent intrinsic health conditions as a group of factors that may impair performance and contribute to fatigue and degree of fitness.

explained. It is suggested that in all cases concerning the PhD Case Study other than perhaps for Building M5 in the 2008-2010 case study[173] density was not an issue. In the WTC 9/11 incident Galea et al (2008) report that density may in fact have masked the fatigue because of the amount of stoppages and hence rest periods due to delays. It is interesting to note that the content analysis of the WTC 9/11 incident (Dwyer and Flynn, 2004) did not agree with this. Nevertheless fatigue is found from all the studies to relate direct to distance where a reduction in descent speed acts as an indicator. This agrees with the experimental studies reviewed by Spearpoint and MacLennan (2012).

Fitness is mentioned in the Exploratory case study as an issue (Beck, 1977), the Content Analysis studies, and actually measured in the Focus Groups using the validated IPAQ system[174] (see questionnaire in the Appendix A3). The studies show a direct link between and the level of exercise of respondents. This provided the main reason for changing the questionnaire in the 2008-2010 case study PDSA Cycles 2 and 3 and suggestions made by the Delphi Group.

The most extensive commonality between the studies in this Chapter relating to the intrinsic core consistency or classification is the one of functional limitations, also known as health conditions. This finding is replicated in Chapter 7 for the 2008-2010 case study trial evacuations survey. Arthritis, osteoarthritis, rheumatics, impaired vision, neurological issues, asthma, stability and postural issues as well as other vestibular and anxiety disorder issues will all affect descent speed and confidence/ This is also reflected in the fear of falling and fear of others in a group where the slow mover thinks they are being forced to move at the same pace as the rest of the group. This is a recipe for falling (Menegomi et al, 2009) and therefore provides a valuable input for the three falls recorded in the 2008-2010 case study. In conclusion it should be noted that all of the factors

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[173] See Chapter 7 and in particular Section 7.6 and Appendix A7

[174] Sjostrom et al (2005)

other than gender is related directly to distance both in terms of the impact of actual and estimated capability.

6.10.2: Table 6-23: The Group (You and Others) Core Consistency

Category or Detailed Factor	Exploratory Case Study Buildings 3 and 7	Content Analysis Study	Focus Groups	Integrated Result (For comparison with 2008-2010 Case Study Results
Group formation	Over 50% formed on floors. 80% in stairs so that Management approach is very important as this Study indicated a higher %age for those with a participative management set up – Building 3.	Accepted that Groups formed and that these were automatic when practised and were linked to participative management styles along with associated commitment	Not really addressed	Groups comprising work colleagues allow for good cohesions and as a vehicle for catering for those who require assistance as per 102 Minutes Study (Zmud, 2007)
Group dynamics	Not really addressed except in terms of formation and structure of the groups e,g building 3. The impact of the slow mover was assessed.	Some inter participant conflict was noted but cohesion was relatively strong. The frustration with the slow mover was mentioned especially in the NY Times Blog Study.	From the individual's point of view they were exasperated with confused groups who had not practised, others obstructing their view of the stairs and the perceived pressure of keeping up with faster members of the group.	Group formation and structure should relate to the work team and yet be part of the procedures. Groups should be structured to include all especially those with needs. Management should encourage this such as evidenced by the woman with the evacuation chair in the 102 Minutes Study (Zmud, 2007). Including this in the planning and practice will make the dynamics positive.
Group behaviour	Delays occurred to merging but groups definitely did defer voluntarily on a possible 50:50 basis. (Altruism)	102 Minutes summarised this as predominantly altruistic behaviour independent of where the group was formed	Not really discussed	Delays should be minimised so that groups can be made smaller possibly centred around those who need assistance. This will still allow for the behaviour of voluntary deferral but will most likely increase the rate of merging. This will also provide for a more cohesive primary group.
Group knowledge	Covered indirectly via observations and familiarity with procedures so that there was no real confusion	This was the second most predominant and related directly to management style and practice such as J.P.Morgan.	Not directly mentioned but it implies that the benefits of practice and simple procedures would decrease frustration with the "noise" of confusion	The Group who know where the stairs are, the space available for resting, the difficulties associated with the stair descent and practice regularly will be familiar with the whole scenario.

The Exploratory case study shows up the rate of group formation being in excess of 50% measured across all the buildings. Group formation can therefore be generalised across all eight buildings and should form part of any integrated summary. The content analysis studies confirm the presence of groups and that they were formed but the frequency was not stated in the content. The Focus Groups did not mention formation.

Group dynamics issues were mentioned in all of the studies. Altruistic behaviours were mentioned but then so was aggressive behaviour due to frustration with slow movers and the stairs were not wide enough for passing. The frequency of aggressive behaviours was small as compared with altruistic behaviours. Slow movers on the other hand were shown to be "fearful" of the rest of the group as they were too embarrassed to ask others in the group to slow down. This "fear" also related to others obstructing the slow mover's view of each step so that foot placement became a problem. The influence of management on group dynamics was also noted and how it was possible through "bottom up" planning to organise groups to successfully help others in need by training them to do so as with the mobility impaired person and the evacuation chair (Zmud, 2007).

Group behaviour in terms of merging can cause extensive delays especially when the size of the groups is unwieldy. The Exploratory case study did show that groups still did defer to others voluntarily usually on a 50:50 basis. The content analysis studies reinforced this. Delays can be minimised through management participating in group formation and actually decreasing the group size so as to allow for easier merging and perhaps increasing the cohesiveness.

The Exploratory case study did not mention group knowledge in detail but was directly seen as a function of management in the Content Analysis studies. This was repeated in the Focus Groups where some of the occupants were frustrated with others who did not know what they had to do and ended up confusing others. Groups who are practiced and know what they have to do therefore decrease the risk to everyone else.

Overall therefore there is strong consistency between the Exploratory Case Study results in Chapter 5 and the combined studies from this Chapter.

6.10.3: Table 6-24: Integrated Results Summary for "Stair Construction and Design" Core Consistency (Extrinsic Factor)

Category or Detailed Factor	Exploratory Case Study Buildings 3 and 7	Content Analysis Study	Focus Groups	Integrated Result (For comparison with 2008-2010 Case Study Results
Stair construction	Narrow treads	No mention	Narrow treads so as face front on and safely place foot on tread	Treads should be a minimum of 280-300mm – not considered beneficial in review of BCA,
	Stair Slope	No mention	Comfortable pitch < 37.5^0	Clope of between 23^0 – 36^0 NZ DBH (2006) Compliance Document D1/AS1
	Uniformity	No mention	No real mention	Uniformity with only construction tolerance allowance – not > 5mm.
	No. handrails	No. Handrails	Two handrails min.	Two handrails minimum all stairs
	Handrail graspability	Not specific enough	Must be reachable and easy to use	Handrails must be at least 900mm above line of nosings with a diameter of 32-40mm. Dichotomy here of stair width as if width exceeds 1200mm there may be a problem with reaching.
	Handrail Use	Minor use of handrails	All participants used handrail even lightly to be prepared for possible fall.	Included but all individuals should be encouraged by management to use the handrails
	Slippery steps	Not mentioned	Not mentioned	Stairs should have a minimum PTV of 36+ UK Slip Resistance Group Guidelines (2011)
	Lighting	Lighting	Lighting to make steps legible and for orientation	Lighting should comply with current Standard and lights should be positioned so as not to cast shadows on the steps.
	Ventilation	Ventilation	Ventilation so that no sweat on handrails and air available for those with asthma and dyspnoea	Ventilation should operate automatically when trial evacuations are run.
Stair environment	Not mentioned	Not mentioned	Stairs must be legible for foot placement, surfaces to contrast for orientation and handrails contrast so that they are visible.	Codes such AS 1428.1 and BS8300 cover accessible stairs but the same requirements re the marking of nosings, providing handrails of a contrasting colour is very important. Walls and stairs should contrast in the dsame way and levels should be clearly identified
Spatial	Stair width/ space for rest	Width to allow for counterflow and resting	Width to allow for overtaking and resting areas for slow movers. Stair void and number of turns per storey should be kept to a minimum.	Width for counterflow, resting areas and overtaking. Also to accommodate larger body ellipse of 800mm (MacLennan et al, 2008a). No of turns per storey should not exceed two and width of void kept to a maximum of 200mm to allow for handrail construction

Narrow treads, steep stairs, non-uniform risers, and availability of handrails were mentioned in all the studies except for the Content Analysis studies. Handrails were included in terms of the number supporting the work of Reeves et al (2008a). All of these therefore form part of the integrated summary to support the 2008-2010 surveys. They can be linked together as a single variable as shown in the factor analysis in Chapter 7 known as "descent risk".

Handrail use appears as an issue in all the studies and therefore is carried forward to Chapter 7 for further comparison. The Focus Groups were vitally concerned about the support that handrails offered. The 2008-2010 case study survey findings did not show up the same concern but the concern still is vital to those who are susceptible to falling. This is vital in enhancing the 2008-2010 survey response. Lighting and ventilation were found to be highly significant right through all the studies and complemented the findings in the 2008-2010 surveys in Chapter 7.

Response on stair "environment" issues especially in terms stairway legibility (contrast especially) was only mentioned in the Focus Group studies but was important to all three groups including the Benchmark Group. This was seen as responsibility of management. Cleanliness was also seen as important between all the studies and this relates to the absence of obstacles as well.

The most interesting response of all across all the studies was that stairs should be wider supporting the findings from the "top down" expert studies such as Peacock et al (2009) and Pauls Fruin and Zupan (2007). Wider stairs allow for conterflow, provide space for overtaking and also for rest. Observations of the 2008-2010 trial evacuations in Chapter 7 support this.

All of the factors in the above table therefore define performance especially in terms of adding to or reducing the risk of falling. Descent risk is summarised by the focus groups by the term "downward spiral". There is every chance that this can impact on the individual's perception of narrow treads and steep stairs as will be shown in the 2008-2010 Case Study results in Chapter 7.

6.10.4: Table 6-25: Integrated Results Summary for "Management and Maintenance" Core Consistency (Extrinsic Factor)

Category or Detailed Factor	Exploratory Case Study Buildings 3 and 7	Content Analysis Study	Focus Groups	Integrated Result (For comparison with 2008-2010 Case Study Results
Management	**Warden communication and direction** not directly covered but seen from observation notes, merging data and also lack of confusion	**Warden communication and direction** Mentioned in 102 Minutes especially in terms of localised awareness and preparedness.	**Warden communication and direction** - Not really mentioned other than the benefit of practice to remove confusion	**Warden communication and direction** should be localised and simple being the result of a participative, simple and well-practised approach
	Evacuation strategy – not really mentioned in data but effects shown in simplicity of uncontrolled strategy when wardens allow individual groups to leave when they are ready as opposed to a phased or sequential strategy is in place and confusion arises. Building 3 and 7 convey these results	**Evacuation strategy** mentioned in terms of benefits of going when you are ready which is associated with an uncontrolled strategy whereas 102 Minutes Study revealed a phased strategy was the official approach. Large tenant with 2000 employees went when they were ready. This what they had practised –	**Evacuation strategy –** not really discussed–	**Evacuation strategy –** This will depend on the height and/or complexity of the building. Whatever strategy is in place it should be based on a high level of preparedness, and be simple and flexible. It should be practised.
	Group formation Building 3 exemplifies this with where the groups were formed and participative style of management	**Group formation:** 102 Minutes shows similar results to the Exploratory Case Study for a large tent with some 2000 employees	**Group formation:** not really mentioned	**Group formation:** Group formation should be localised and participative to result in a structure that can assist and result in a high level of cohesion.
Maintenance	**Lighting** mentioned in survey with a positive response for both buildings. A significant factor in the 1977 Canadian Study.	**Lighting** – not really commented on.	**Lighting** – only mentioned as part of maintenance but did mention the aspect of vi8sible stairs.	**Lighting** Must be maintained to Standard designed and altered where steps are placed in shadows
	Ventilation – Mentioned concerned with individual performance and a significant factor in 1977 Canadian Study	**Ventilation –** not really mentioned	**Ventilation –** not really mentioned	**Ventilation** Must be maintained to Standard designed and altered where not triggered with evacuation and providing adequate flow of air to assist with individual performance where hot conditions would result
	Cleanliness and no obstructions – significant factor in 1977 Canadian Study and people general satisfied in Buildings 3 and 7.	**Cleanliness and no obstructions –** included generally in results but no specific comments	**Cleanliness and no obstructions –** not really commented on.	**Cleanliness and no obstructions –** Notices must be displayed so that stairs cannot be used for storage or obstructions left after maintenance activities, Stairs must also be clean so that surfaces not slippery

6.10.4: Table 6-25 presents the comparison of all the Studies in Chapter 5 and 6 for the Management and Maintenance Core Consistency. Warden communication and direction is common across all the studies in one way or another. Individuals need to know what they have to do. If the communications are simple and clear and the trial evacuations are held regularly then confusion can be kept to a minimum avoiding situations such as that in the Clark County fire (Proulx et al, 2006).

The importance of a simple and inclusive evacuation strategy cannot be overstated. There is a real case to be made for the uncontrolled (one out- all out) strategy because it is simple and can be practiced readily. The findings of the WTC 9/11 Content Analysis showed the importance of a simple strategy and management commitment and this was confirmed by the Focus Groups.

All the studies confirm the importance of warden-occupant or employee interaction. One valuable point made in the WTC9/11 incident content analysis is the benefit of inclusive planning of group assistance where the group members are trained in the assistance they are required to provide one of their members thereby decreasing the risk to them and increasing the value of the assistance they provide[175].

Lighting, ventilation and cleanliness were all factors mentioned as being highly significant in the Exploratory case study. This was not continued on in the other studies. It was seen as being highly significant and was required to form part of the 2008-2010 case study analysis.

The table therefore shows the importance of warden-occupant interaction and direction especially in terms of clear communication and practised stair descent to increase familiarity with procedures including safely assisting others. Group formation is catered for in the Exploratory Case Study and the Content Analysis Studies to provide complete information on the frequency of formation and the likely group structure/ cohesiveness. The most significant finding of all deals with the importance to occupants of maintenance (cleanliness, illumination and ventilation).

6.11 Summary and Conclusion

6.11.1 Aim

The aim of the PhD Study is:

[175] The case of the evacuation chair (Zmud, 2007)

"To study the performance of mature age office workers descending multiple flights of stairs in trial evacuations in the context of extrinsic and intrinsic factors[176]".

The main thrust of this aim is to study the estimated and actual performance of mature age office workers in descending multiple flights of stairs in the context of the intrinsic and extrinsic factors that impact significantly on this task. This context is represented by the core consistency classifications described in Section 6.10.1: Table 6-22 to 6.10.4: Table 6-25.

6.11.2 Individual performance and intrinsic factors

The measure of individual performance in the Exploratory Case Study was limited by the paucity of available data concerning age, gender and BMI. Data that is available is self-reported data that may or may not reliable e.g. fatigue. There was sufficient data available to test the relationship between fatigue as a measure and the number of storeys occupants estimated they could cope with. The results as presented in Chapter 5 show that fatigue can predict 76% of the variance (exponential x/y relationship) in the number of storeys individuals estimate they can cope with. The method used together with the depth of data available at the time can be challenged so that a greater reliance needs to be placed on the Focus Group Studies. Here waist circumference was used as a measure of metabolic condition (Booth et al, 2002). Waist circumference predicted a minimum of 38% of the variance in the number of storeys an individual estimate they can cope with. Both of these regression measures were statistically significant ($p<.05$ overall). It can still be reasonably concluded that fitness measures which are also related to most metabolically based conditions are a reliable performance measure that satisfy the Aim.

The "reasonable conclusion" can still be challenged especially in terms of advice received from the UK Delphi Sub Group where they maintained that

[176] The framework representing the contextual factors are further tested by Objective 04 as part of an inclusive planning and assessment toolkit

descent speeds should be used as the predictor variable. Descent Speeds were not available for the Exploratory Case Study. They were derived for the Focus Group Studies (including the BMI Benchmark Group used as a control group) to support the performance measure. This was consistent with similar studies (Tiedemann et al, 2007 and Hulens et al, 2003) .The speeds from the Focus Group Studies were compared with those from other seminal studies mentioned by Peacock et al (2012). A similar comparison was carried out between engineering and health science research by Spearpoint and MacLennan (2012). The comparison shows that they follow the same pattern when “tied” to functional limitations. The missing factor is distance or number of storeys traversed. This element is included and is critical as far as the Aim is concerned as per the comments of Shields et al (2009) and Ayis et al (2007). Peacock et al (2009) show that as distance increases the speed decreases. The reduction in speed relates strongly to the intrinsic factors as summarised in Table 6-22. The Individual Performance measure developed to this stage satisfies the Aim and is an internally valid construct in terms of case study method (Yin 2009). It is further supported by studies such as those developed by others such as Leake et al (1991), Tiedemann et al (2007), Hulens et al (2003) and Ayis et al (2007).

6.11.3 Extrinsic factors

The main extrinsic factors (core consistencies) of the Group, Stairs and Management, are summarised in 6.10.2: Table 6-23 to 6.10.4: Table 6-25. Not all the relationships can be quantified because of the nature of the data and the size of some of the samples. Similar studies have been cited and described that support the relationships. These relationships also correspond with the Delphi Group Ishikawa Charts. Seeing the Aim of the Thesis is concerned with the “spine” of the model and the branches represent each of the core consistencies, the contextual impact of the extrinsic factors or core consistencies is justified.

6.11.4 Application to the 2008-2010 Trial Evacuation Case Study

Chapters 5 and 6 as summarised in Tables 6-22 to 6-25 link the Exploratory Case Study with the Content Analysis and Focus Studies. The resultant findings will therefore be used to explain and enhance the issues raised from the results in Chapter 7.

Chapter 7: Results and Discussions 2008-2010 Case Study and Comparison with Chapters 5 and 6.

7.1 Introduction

Chapter 7 deals with that part of the 2008-2010 Case Study highlighted in light blue in Figure 7-1 below:

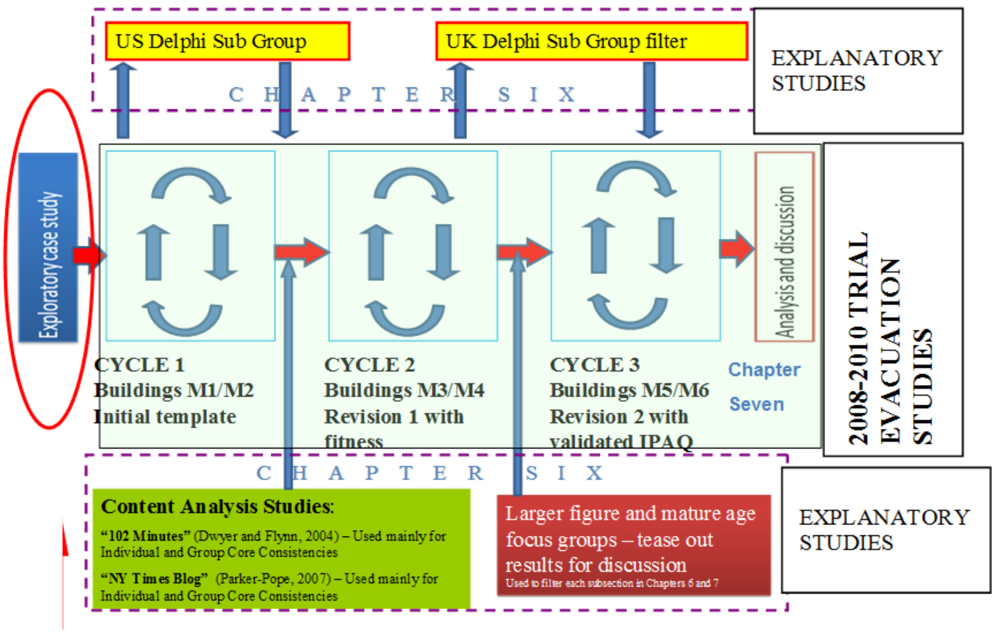

Figure 7-1: 2008-2010 Case Study in relation to PhD Study Research Process

Before introducing the main part of the PhD case study (a multiple case study) being the 2008-2010 case study it is necessary to show how the Exploratory case study is integrated with the latter. The intention was to directly compare results from two representative buildings. The two buildings selected were Buildings 3 and 7 and the reasons for selection provided in Chapter 5. Buildings 3 and 7 are known as the "Exemplar Buildings". They are included with the six 2008-2010 case study buildings M1-M6 for the following analysis in addition to the issues brought forward from Chapter 6:

- To form part of a combined factor analysis of the physical data gathered from the measurement of the stairs as per the templates in Chapter 3 and Appendix A3.
- As a direct comparison between equivalent results comparing the contextual factors to see if any direct comparisons could be made longitudinally between cases to confirm or otherwise the opinions of Pauls, Fruin and Zupan (2007) that the descent capability or performance of individuals had deteriorated over the last three decades.

The chapter is divided into the following sections:

- 7.2 2008-2010 Case Study Survey – Descriptive Statistics and tables where patterns (trends) between buildings are examined (Hak and Dul, 2007) and possible generalisations made (Yin, 2009)
- 7.3 2008-2010 Case Study Survey – Correlations and Factor Analysis. A correlation matrix is prepared to establish significant relationships between the contextual factors themselves as well as with thr individual descent capability or performance.
- 7,4 2008-2010 Case Study Results and Discussion linking core consistency factors with performance. This is where correlations are used to confirm or challenge patterns that were established.
- 7.5 Comparison with output from Chapters 5 and 6. This where the results from the two exemplar buildings from the Exploratory case study are compared with those from the 2008-2010 case study trial evacuation surveys. It is also where the integrated

findings from the Content Analysis and Focus Group studies are compared with the 2008-2010 case study surveys.

- 7.6 Triangulation of 7.5 with Observed and Measured Data. The method of triangulation was presented in Chapter 3. Spread sheets and schedules of the measured data may be found in Appendix A7 under the same section number. It is here that survey respondents are "positioned" with the observed descending group so that their descent speeds can be established and compared with their intrinsic characteristics to esatblish the potential for falling (Menegomi et al, 2009).

- 7.7 Conclusions and linkage with Chapter 8.

7.1.2 Co-ordination with Appendix A7

Results for buildings M1 to M6 comprise three sets of data:

- Time based data presented in the form of stair descent charts with the Y-axis being the number of storeys above ground and the X-axis the time taken to move through that number of storeys.

- Data analysed from the survey of a selected sample of participants from each one of the buildings who can be "located" on these stair descent charts.

- Data comprising comments from stair descent and video-replay observers who are seen as being "embedded" in the 2008-2010 Case Study.

The output from the above is presented in the form of charts, graphs, tables and schedules. These will be included in the Appendix A7. This Appendix will follow the same numbering system as Chapter 7 so that direct comparisons can be made.

7.1.3 Hierarchy of Survey Results and Presentation Pattern

Descriptive statistics in the form of frequencies are presented for each building according to the appropriate PDSA Cycle to paint a picture of the distribution of responses in terms of each of the core consistencies derived in Chapter 6 being;

- The Individual (YOU) – intrinsic variables
- The Group (YOU & OTHERS) - extrinsic variables
- The Stair (STAIR CONSTRUCTION & ENVIRONMENT) – extrinsic variables
- Management (EMERGENCY MANAGEMENT & MAINTENANCE) – extrinsic variables

In order to satisfy the objectives of the PhD Study it is necessary to establish whether inter and intra core consistency variable relationships are significant or not. The pattern of the relationships is explained in Figure 7-2 below;

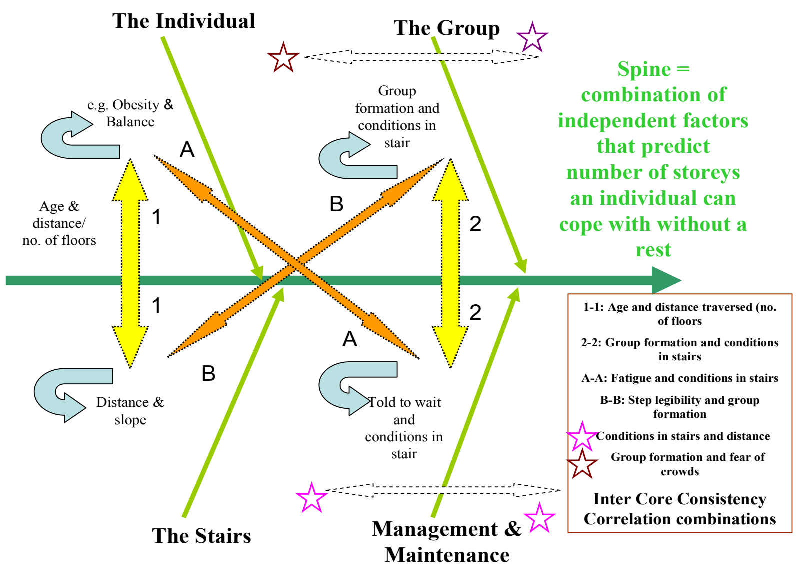

Figure 7-2: Inter and Intra Core Consistency Relationship Framework for Correlations

The core consistency classifications of the intrinsic and extrinsic factors are maintained throughout this chapter.

The curved arrows in each segment of the figure represent the intra variable relationships for each core consistency with examples against each arrow. The inter core consistency variable relationships are:

- 1-1: The Individual and the Stairs
- 2-2: The Group and Management
- A-A: The Individual and Management
- B-B: The Group and Stairs
- *-* The Individual and the Group and The Stairs and Management

Bivariate correlation matrices are prepared for each of the above to establish those relationships that are significant. Three levels of significance are established to test the strength of the association between variables as being, *p≤.001 (highly significant), p≤.01 (reasonably significant)* and *p≤.05 (moderately significant)* so that these relationships can be "ranked". The ranking is studied further by factor analysis of the factors relating directly to the individual and the stairs as a means of simplifying some of the "clusters" that may be formed by the significant relationships and ordering these clusters as components. This approach also provides for greater clarity for triangulation with the appropriate measured and observed data[177].

The objectives support the aim of the PhD Study in that they provide the context. Regression analysis is used to establish those factors which are the significant predictors of the estimated performance of the mature office worker. The dependent variable represents the main thrust of the Aim which is a measure of performance or descent capability (See also Figure 7-3 below.)

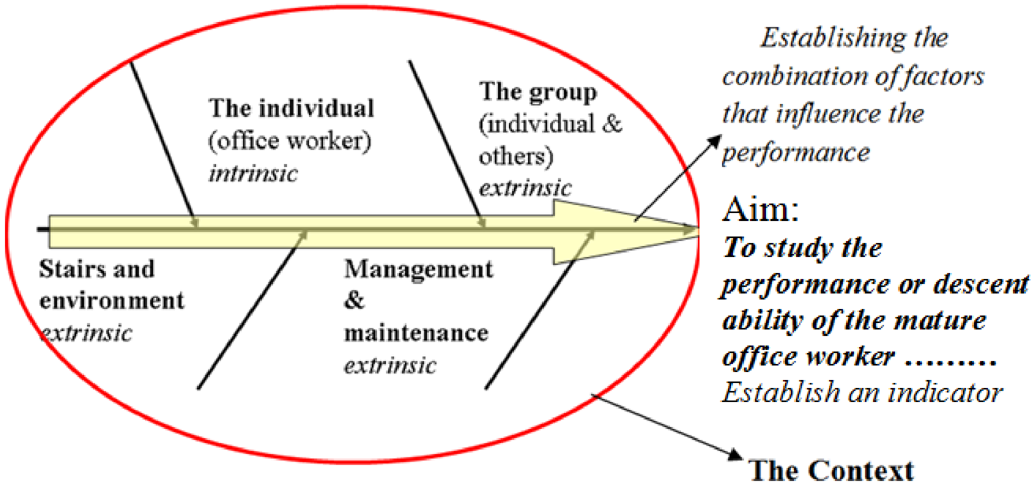

Figure 7-3: How Regression Analysis delivers the Aim of the PhD Study.

[177] Factor analysis of two sets of complex data, one gathered by survey and the other by direct measurement reduces the data into components which are easier to compare via triangulation.

7.1.4 Presentation of Video and Observed Data

Individuals' descent progress the video camera recordings together with key measurement points (e.g. intersection of landing with first step and also level numbers marked on the walls) were transferred from the recordings to Excel® spread sheets utilising the internal time clock information shown on the applicable "time stamp" for each building (M1-M6) and each person or occupant**.** Triangulation between observers' recorded timestamps and the video equivalents was used to achieve internal reliability for the transferred data. No discrepancies were found as the observers were used to form the "skeleton" of the descent chart.

The "evacuation progress" of each occupant or participant is then presented in graphical format on stair descent charts similar to those used by Peacock et al (2012) where the Y-axis is divided into intervals representing each level. The X-axis is the evacuation time in seconds. The progress of each occupant is represented by a path trace or colour coded line. This "time stamp" for each occupant can be determined at the data points on the chart which is included in electronic format in Appendix A7[178].

Comments from the "video" observer, triangulated with comments from evacuation site observers[179] are also presented on the stair descent charts in Appendix A7 as standardised symbols that relate directly to an associated legend. A chart delivered in this format is used as the major tool for triangulation between on-site observations and measurements and analysed survey data.

Descent speeds and densities are presented separately in traditional graphs. Of special interest here are comparisons between density and descent

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[178] DVD is located in Volume 2 so that results can be interrogated.

[179] The video observer was able to see the visual images and record their own comments on to the descent chart. These comments were also triangulated with the comments of the observers who took part in the evacuation from the Dictaphone sound files. One of the main responsibilities of the trial evacuation observer was to record their progress in sound format e.g. level by level, number of people in the associated group, handrail use etc.

speeds which can be directly compared with a participant's perceptions concerning "conditions in the stairs" and whether or not the participant was a member of a group or not, each measured in the survey. Survey variables such as "entered the stair with a friend" can be meaningfully triangulated with the "apparent grouping of occupants" shown on the stair descent charts.

7.1.5 Presentation of Measured Data and Results

As described in Chapter 3 the measured data for each building is presented in a table for all buildings. The factors included are those determined in conjunction with the Delphi Group with those from the Literature Review in Chapter 2 along with the Exploratory Study dataset.

Much of the data is therefore *interval* data as it has a set scale with a zero starting point. Examples are the width of stair treads recorded in mm. Some of these data are transformed into ordinal data comprising scores using another form of rating scale. This scale does not have regular intervals. An example of this is where tread widths may be graded on a scale of 1 to 5 going from hazardous to completely safe. The grading in the instance of this PhD Study was carried out by the author as an expert immersed in the overall study (Yin, 2009). The grading is also based on the literature review in Chapter 2 e.g. from Templer (1992) to Roys (2006) and Alderson (2010).

The ordinal data can be readily used in factor analysis and is also more compatible for triangulation with the survey data based on the Canadian questionnaire (see Chapter 4) which also utilises the *Likert* scale and the simple hazard rating scale mentioned above. Examples of this approach are used in some Building Codes e.g. D1/AS1 "Access Routes" (Department of Building and Housing, 2011).

In order for the factors represented by the measured data to be more meaningful it was entered into SPSS V16, aggregated and the number of variables reduced into a small number of components using factor analysis. The results of the factor analysis are presented in a table where the input variables are listed in the variable column as shown below in Figure 7-4:

Input variable or factor	Component 1 (e.g. climbability)	Component 2	Component 3	Component 4	Component 6	Component 7
Width of treads etc.						

Figure 7-4: Specimen Factor Analysis Outcome Table

The Component columns do represent a form of ranking where the components comprise clusters and where the component can explain as much variance in the original data as a single variable. Components that cannot explain more than 5% of the variance in the original data are not worth considering (Hinton et al, 2005). Selection or cut off values for the variables "clustered" around each component have been set at ≥ 0.7 as agreed with the UK Delphi Group. In certain instances variable values between 0.6 and 0.7 are considered where they can be supported by observation or research.

Measured data is used extensively to test survey participant response and enhance the analysis of the data. This data has also been reduced via factor analysis. The triangulation framework is shown in Chapter 3. The reduction of data into a smaller number of variables allows for a more meaningful comparison between the two data sets. Two other important measured components are distance and height traversed per storey as mentioned in the previous section and also a similar study of six buildings up to 31 storeys in height (Peacock et al, 2009). The "STAIR" factors are measured directly off the site drawings which are all fully dimensioned. The site drawings are presented in Chapter 4. The distances are used to establish descent speed which is used to assess the degree to which the survey respondents were limited by their self-declared functional limitations and/or level of fatigue or fitness in the context of other studies presented in Chapters 5 and 6.

7.2 2008-2010 Case Study – Descriptive Statistics – Results and Discussion.

Descriptive Statistic Analysis Results are presented for each PDSA Cycle. Buildings M1-M4 are known as the non IPAQ[180] buildings and M5 and M6 as the IPAQ[180] buildings.

7.2.1 Overview

Buildings M1and M2

Building M1 is the 10 storey office building located in Christchurch but which has now been demolished after the earthquake. See Chapter 4 for the full description. The evacuation strategy used was the uncontrolled type ("one out all out"). Occupants all started to move on the sounding of the alarm. The linking of the scissor stairs caused some delays. The number of respondents was 104. The use of the additional "follow up" questionnaire did not work so that the overall questionnaire was modified for M3 and M4 to provide the additional information required on fitness.

Building M2 is a 36 storey office building located in Dubai, UAE. See Chapter 4 for the full description. On the day of the trial evacuation the following events compromised the exercise and the data retrieval:

- The fire alarm sound levels were inaudible on some floors and failed to operate on others.
- The temperature within the stairwells was 40^{0}C+. The stairwell ventilation failed to operate.

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[180] Sjostrom et al (2005)

- Many occupants refused to evacuate e.g. 34^{th} floor. Others used the lifts.

- 50% of the observers did not enter the stairs where the alarms failed to operate.

- Small video cameras fell from their adhesive mountings due to the internal conditions.

- There were two observed falls where the occupant came to rest on the ground due to different factors.

The author[181] made the decision to include M2 because of these falls and also because of the stairs and their environment (temperature of 40^0C and no ventilation).

Buildings M3 and M4

Building M3 is a 19 storey office building located in Manchester in the UK. Building M4 is a 26 storey office building located in Wellington, New Zealand. The follow up questionnaire was dispensed with and the questionnaire modified to include fitness related questions (see Appendix A7). The main modifications related to the respondent's exercise regime and measures of "stair-use difficulty". Resultant responses were to be analysed to test the relationship between fitness, practice and other functional limitations and distance traversed (actual and estimated). This change from PDSA Cycle 1 still did not totally overcome the limitations of self-reporting (Chan, 2009) but did use a method similar to that of Verghese et al (2008) where respondents reported on their stair climbing ability. Descent speed is also incorporated into PDSA Cycle 2 in line with recommendations from the UK Delphi Sub Group.

[181] Case study research methodology allows and actually recommends this approach (Yin, 2009)

Buildings M5 and M6

The questionnaire for these buildings was modified to incorporate a validated self report questionnaire / survey system known as the International Physical Activity Questionnaire (IPAQ) [180]. Building M5 is an 18 storey office building located in Wellington, New Zealand. Building M6 is a 34 storey office building in Sydney, Australia. The evacuation strategy for M5 is an uncontrolled evacuation ("one out, all out") and a sequential strategy for M6. There were extensive delays in M5 where the percentage of occupants suffering from fatigue were reduced due to the reduced descent speed and delays due to merging. This could be a case of density masking fatigue (Galea, 2008).

Survey results for Buildings M5 and M6 are based on the International Physical Activity Short Form Questionnaire (Sjostrom et al, 2005) and further tested by the respondent's group descent speed (UK Delphi Sub Group).

The M6 Building Organisations required that the survey be administered electronically. Survey Monkey® was suggested. This was found to be incompatible with "Tenant" systems. A customised compatible system based on Excel® was suggested and used. The M6 Trial Evacuation took place but problems were experienced in extracting the data associated with the respondent's perception of the "Stairs". Only frequencies are available for comparison. This is still considered to be acceptable as it will still allow for pattern-matching with similar results from PDSA Cycles 1 and 2. Generalisations can still be made (Yin 2009). Where the Excel® did not compromise matters, the data was still used but was aggregated with Building M5 for bivariate correlations.

The short form IPAQ questionnaire (Sjostrom, 2005) was integrated into the Questionnaire as previously stated as part of the modification of the survey instrument between PDSA Cycle 2 and 3 as described in Chapter 4. The data was converted from the time noted against the various levels of activity into MET[182]minutes/week. Data is transformed into categorical data as follows:

- Category One – Low where the total METS is less than 600 per week
- Category Two – Moderate where the total METS is between 600 and 2999METS per week
- Category Three – High where the total METS is greater than 3000METS per week

The IPAQ Instruction Manual as described by Sjostrom et al (2005) was used to code and analyse the data. PDSA Cycle 3 also involved the use of a modified adult fatigue short form survey instrument as prepared by PROMIS[183] which was also to be tested as a predictor of the number of storeys a respondent could cope with. This action was taken as an extension of the findings from the Exploratory Case Study where there was a moderately significant relationship between "fatigue" and number of storeys a person estimated they could cope with without holding others up varying between R^2 of 0.6-0.76 but this would only be moderately significant.

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182 MET is the metabolic equivalent of a task. It is a physiological measure expressing the energy cost of an activity. Values range from 0.9 for sleeping to 18 which is running at 17.5Km/hr. It is referenced to 4.1.84Kj-kg^{-1}h^{-1}.

183 PROMIS – Patient-Reported Outcomes Measurement Information System as described by Rose et al (2008). This system is similar to the IPAQ system (Sjostrom, 2005) in that as a self reporting tool it has been validated (Rose et al, 2008).

Results and Comments

Figure 7-3 represents a framework of relationships between context and the individual performance indicators. It is intended that the critical contextual factors within each core consistency which are the “root cause” of the occupant’s estimated descent ability can be clearly identified. The “spine” of the Ishikawa Chart represents the most likely combination of factors that may or may not influence this perception. The survey results for PDSA Cycle 1 are based on the initial Canadian Questionnaire where fitness was loosely related to fatigue reflect the results for Buildings 3 and 7 being the exemplar buildings from the Exploratory Case Study (see Chapter 5). The level of significance in each case was moderate ($p<.05$). As a result of this relationship and the support provided by the 1977 Canadian Study (Beck, 1977) there appears to be some internal reliability in the Exploratory Case Study dataset between variables relating indirectly to fitness or functional limitations and estimated descent ability. There is some support to continue the function of performance in the 2008-2010 Case Study.

Descriptive Statistics Tables

The descriptive statistics results are presented in the following Table 7-1 to Table 7-4. These tables are presented in prior to discussion in the text as they list all six buildings together. Reference is made to all four tables in each subsection for each core consistency or classification.

Variable	Frequencies and Building Numbers												
Level No.	M1(n = 104) † 10		M2 (n= 136) † 36		M3 (n = 106) † 19		M4 (n = 99) † 27		M5 (n = 62) † 18		M6 (n = 169) † 32		Comments
Evac (E) & (W)work	E %	W %	E %	W %	E %	W %	E %	W %	E %	W %	E %	W %	
1	17.3	17.5	1.5	0.0	10.5	10.6	Cp	Cp	0.0	0.0	4.2	3.6	M4 first 4 levels used for car parking
2	15.1	16.5	1.5	1.4	4.9	4.8	Cp	Cp	0.0	0.0	3.6	3.6	
3	1.0	1.0	8.8	8.5	2.9	2.9	Cp	Cp	0.0	0.0	3.6	3.0	
4	11.5	11.3			9.5	9.6	Cp	Cp	6.7	6.7	0.0	0.0	Administration and control centre on Level 4 of M2 – no evacuation
5	2.9	2.1	5.1	5.7	3.8	3.8	14.6	15.2	0.0	0.0	3.0	3.0	
6	10.6	11.3	5.9	5.7	2.9	2.9	7.3	7.6	13.3	13.3	3.0	3.0	
7	11.5	9.3	2.2	2.8	13.3	13.5	8.3	8.7	3.3	3.3	2.4	3.0	
8	6.7	8.2	4.4	5.0	8.6	8.7	11.5	12.0	11.7	11.7	9.5	9.5	
9	10.6	10.3	8.1	7.8	0	0	1.0	1.1	10.0	10.0	3.0	3.0	
10	12.5	12.4	4.4	5.0	7.6	6.7	5.2	3.3	10.0	8.3	4.2	3.6	
11					5.7	4.8	7.3	5.4	8.3	10.0	3.0	3.0	
12					8.6	9.7	5.2	5.4	6.7	6.7	1.8	1.8	Levels 10 & 11 in M2 evacuated via lifts
13			0.7	0.7	4.8	6.7	0	0	0.0	0.0	4.2	4.2	
14			0.7	0.7	4.8	4.8	2.1	2.2	13.3	13.3	3.0	2.4	
15					0	0	6.2	6.5	0.0	1.7	4.8	3.6	Floors 15 and 16 in M3 were generally exempted
16					0	0	0	0	13.3	11.7	3.6	4.2	Floors 16-18 in M4 were generally mid-level plant rooms
17			0.0	0.7	12.4	11.5	0	0	0.0	0.0	4.8	4.2	
18							0	0	3.3	3.3	4.2	4.8	Level 18 evacuated via lifts in M2 or did not evacuate
19			0.7	0.0			1.0	1.1			2.4	2.4	
20			8.1	7.8			0	0			3.0	3.6	No responses from Level 19 in M4
21			0.0	0.7			1.0	1.1			PR	PR	
22			3.7	3.5			9.4	9.8			PR	PR	
23			6.6	5.7			12.5	13.0			PR	PR	
24			3.7	3.5			1.0	1.1			3.6	4.2	
25			4.4	4.3			1.0	1.1			3.0	3.6	
26			2.2	2.1			4.2	5.4			3.0	3.6	
27			6.6	6.4			1.0	0			4.2	3.6	
28			11.8	13.5							1.8	1.2	
29			0.7	0.7							3.6	3.6	
30											2.4	2.4	Levels 30 and 31 in M2 evacuated via lifts / did not evacuate
31											4.8	6.0	
32			0.7	0.7							3.0	3.0	
33			0.7	0.7									
34			4.4	4.3									
35													Level 35 in M2 refused to evacuate
36			2.2	2.1									

†Indicates number of Levels; (n = XX) is base sample size for each building and applies to all tables in 2008-2010 Case Study
Green highlights represent either no respondents or where levels comprise plantrooms. Yellow highlight represents levels higher than building in question
Each cell represents percentage of the respondents of the sample represented from that storey in the building concerned

Table 7-1: 2008 – 2010 CASE STUDY: INTRINSIC CORE CONSISTENCY PDSA CYCLES 1-3: PERCENTAGE FREQUENCIES: LEVEL NUMBERS ON WHICH OCCUPANTS STARTED EVACUATION AND WORKED

Variable	Buildings and Frequencies						
	M1	M2	M3	M4	M5	M6	Comments
Age							
<20	1.0	0.0	0	0	1.6	0.6	
21-44	76.2	90.5	64.4	64.5	62.3	67.5	
45-64	21.9	9.5	28.8	32.3	36.1	31.9	
65-74	1.0	0.0	6.7	3.2	0.0	0.0	
Gender							
Male	33.0	63.2	59.4	58.9	41.0	45.5	
Female	67.0	36.8	40.6	41.1	59.0	54.5	
Height							
>1.39m	0.0	3.6	0	1.1	0.0	0.0	
1.4m	3.9	13.1	0	0	0.0	0.0	
1.5m	0.0	0.0	5.8	8.6	8.6	9.6	
1.6m	54.3	43.8	28.0	20.3	30.9	33.6	
1.7m	1.0	0.7	31.2	41.4	36.0	33.1	
1.8m	31.4	34.3	30.0	22.3	18.7	19.7	
1.9m	5.8	2.2	3.0	4.1	5.8	4.0	
2.0m	1.0	0.7	2.0	2.2	0.0	0.0	
Body Mass Index							
Underweight	1.0	5.2	1.0	1.1	3.3	1.9	
Normal weight	42.9	38.8	48.5	46.2	60.0	53.8	
Overweight	37.1	38.1	32.0	37.6	25.0	31.2	
Obese Class 1	6.7	3.0	6.8	5.4	6.7	10.6	
Obese Class 2	8.6	11.2	8.7	5.4	5.0	4.4	
Obese Class 3	3.8	3.4	2.9	4.3	0.0	0.0	
Fitness (M1-M4)							**Fitness Level (Sjostrom et al, 2005) M5 & M6**
Fit	34.3	30.6	39.8	25.8	>50%	<50%	
Overweight/with health condition	35.2	34.3	36.9	44.1	11900	6099	Maximum
Obese with condition	13.3	17.2	16.5	18.3	3908	1995	Mean (50%)
Very obese with condition	9.5	9.0	4.9	6.5			
Morbidly obese with condition	7.7	9.0	1.0	5.4	365	49.5	Minimum
Shoe size							
Min	250	251	243	260	245	235	
Max	328	352	319	352	330	335	
Mean	289	294	281	289	290	280	

Table 7-2: 2008 – 2010 CASE STUDY: INTRINSIC CORE CONSISTENCY PDSA CYCLES 1-3: FREQUENCIES: INTRINSIC CORE CONSISTENCY – OCCUPANT CHARACTERISTICS

Variable	M1	M2	M3	M4	M5	M6	
Requiring Assistance	2.9	4.6	0.9	0.0	0.0	5.9	
Health Conditions							I
Heart	1.0	3.6	2.8	1.0	3.4	3.5	N
Asthma/ Dyspnoea	11.4	7.9	3.7	12.4	15.5	9.4	T
Prior stroke	2.9	0.7	0.9	2.1	3.4	0.6	R
Type 2 Diabetes	2.9	0.7	2.8	3.1	3.4	2.9	I
Balance	2.9	0.7	4.7	4.1	6.9	2.9	N
Arthritis	3.8	2.1	5.6	7.2	5.2	2.9	S
Reduced mobility	8.6	5.7	11.2	8.3	10.4	6.5	I
Reduced hearing	3.8	0.7	2.7	7.3	3.4	1.8	C
Reduced vision	4.8	4.3	5.6	12.4	15.5	3.5	
Loss of memory	2.9	0.7	0.9	4.1	1.7	1.2	
Fear of falling	2.9	0.7	2.8	13.4	6.9	7.1	
Fear of crowds	2.9	0.7	1.9	7.2	5.2	3.5	
Number of health conditions							
One	23.8	25.4	13.1	19.6	25.8	20.6	
Two	2.9	2.8	0.0	9.3	6.5	5.3	
Three +	2.9	1.4	6.5	10.3	6.5	2.4	
Stair entry control and Evac. Procedures							M
Waiting for people to pass (told)	16.8	17.4	9.5	10.5	19.3	2.4	N
Told to wait	1.0	13.8	1.0	0.0	0.0	23.5	G
Queuing	16.8	8.3	5.7	18.9	3.5	36.1	M
Evacuation experience	85.6	33.3*	72.0	83.3	83	85	T
Designated stair	100#	50#	83.0	81.8	86.2	97	
Group formation							G
Entered stair with friend	31.4	79.5	48.1	54.7	76.7	67.3	R
Formed group at work location	63.6	71.3	74.5	100.0	46.2	75.9	P
Voluntary deferment (merging)	11.9	6.4	12.4	17.9	22.8	2.4	
Conditions on stairs – perceived density							M
Alone	26.9	6.5	10.5	30.2	0.0	2.0	N
Few others around	69.2	50.0	71.4	67.7	5.0	15.0	G
Crowded but moving	2.9	39.8	15.2	2.1	21.0	76.0	M
Very crowded and slow	1.0	3.7	2.9	0.0	74.0	7.0	T

Table 7-3: 2008 – 2010 CASE STUDY: INTRINSIC CORE CONSISTENCY PDSA CYCLES 1-3: FREQUENCIES - HEALTH CONDITIONS (FUNCTIONAL LIMITATIONS), MANAGEMENT AND GROUPS

Factor / Core Consistency	Variable	Building M1			Building M2: 17† 114)∞			Building M3			Building M4:			Building M5:			Building M6:		
		Agree/ Extreme – moderate/	Neutral / Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral / Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral / Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral / Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral / Slightly	Disagree/ Not at all	Agree/ Extreme – moderate/	Neutral / Slightly	Disagree/ Not at all
Perception of Stair Construction and Environment	**Hndrl easy to find**	**88.1**	**7.9**	**4.0**	**95.3**	**0.9**	**3.8**	**92.3**	**6.7**	**1.0**	**96.9**	**2.1**	**1.0**	**98.3**	*	**1.7**	**93.0**	*	**7.0**
	1st step easy	**53.2**	**37.5**	**9.3**	**88.5**	**7.7**	**3.8**	**92.2**	**5.8**	**2.0**	**97.9**	**2.1**	**0.0**	**96.7**	*	**3.3**	**95.0**	*	**5.0**
	Each step easy	**47.4**	**40.2**	**12.4**	**88.6**	**7.1**	**4.3**	**91.4**	**6.7**	**1.9**	**95.9**	**4.1**	**0.0**	**96.7**	*	**3.3**	**94.0**	*	**6.0**
	Last step easy	**34.0**	**40.2**	**25.8**	**76.2**	**13.4**	**10.4**	**90.3**	**6.8**	**2.9**	**96.9**	**3.1**	**0.0**	**96.6**	*	**3.4**	**94.0**	*	**6.0**
	Stairs too steep	**20.8**	**33.3**	**45.9**	**48.5**	**28.7**	**22.8**	**23.0**	**25.0**	**52.0**	**9.3**	**35.1**	**55.6**	**11.7**	*	**88.3**	**28.0**	*	**72.0**
	Treads too small	**27.7**	**31.7**	**40.6**	**45.5**	**27.3**	**27.2**	**26.0**	**24.0**	**50.0**	**20.6**	**33.0**	**46.4**	**18.9**	*	**81.1**	**31.0**	*	**69.0**
	Too many flights	**8.8**	**23.5**	**67.6**	**46.1**	**26.3**	**27.4**	**10.6**	**25.0**	**64.5**	**10.4**	**30.2**	**59.4**	**6.8**	*	**93.2**	**30.0**	*	**70.0**
Condition after descent	**Lower leg problem**	**9.7**	**12.6**	**77.7**	**52.4**	**17.8**	**29.7**	**12.5**	**11.5**	**76.0**	**9.3**	**14.4**	**78.3**	**7.0**	*	**93.0**	**21.0**	*	**79.0**
	Dizzines/Vertigo	**3.9**	**11.7**	**84.4**	**39.4**	**22.2**	**38.4**	**9.6**	**7.7**	**82.7**	**3.1**	**17.5**	**79.4**	**6.8**	*	**93.2**	**26.0**	*	**74.0**
	Dyspnoea	**2.9**	**12.6**	**84.5**	**38.3**	**19.6**	**42.1**	**9.7**	**8.7**	**81.6**	**1.0**	**12.4**	**86.6**	**3.4**	*	**96.6**	**11.0**	*	**89.0**
	Chest	**1.9**	**10.7**	**87.4**	**30.7**	**20.8**	**48.5**	**3.9**	**7.7**	**88.4**	**0.0**	**11.6**	**88.4**	**1.7**	*	**98.3**	**4.5**	*	**95.5**
	Fatigue generally	**5.9**	**12.6**	**81.5**	**48.1**	**14.4**	**37.5**	**6.7**	**13.5**	**79.8**	**8.3**	**14.4**	**77.3**	**4.8**	*	**95.2**	**24.5**	*	**75.5**

Table 7-4: 2008 – 2010 CASE STUDY: INTRINSIC CORE CONSISTENCY PDSA CYCLES 1-3: FREQUENCIES - PERCEPTION OF STAIRS AND CONDITION AFTER DESCENT

7.2.2 The Individual – Descriptive Statistics

Buildings M1 and M2

The intrinsic characteristic profile is shown in above. The percentage of office workers over the age of 45 years which is to be used for the classification of the mature age worker (Australian Human Rights Commission, 2008) is 22.9% in Buildings M1 which compares with the 19.6% in the 1977 Canadian Study (Beck, 1977) and is below the percentages projected for the next decade (Dixon, 2003). In building M2 the percentage of mature age workers is only 9.5%. This difference may be due to culture (Table 7-5). (Yeboah, 2007) shows that in the year 2000, 62.5 % of the workforce (including non UAE nationals) was less than 44 years in age. Given that the retiring age is 60 years of age the estimated percentage of mature age workers is slightly less than 10%.

Age Group	Male		Female		Total	
	Number	%	Number	%	Number	%
0-4	140000	4.50	133000	4.28	273000	8.78
5-14	284000	9.14	256000	8.24	540000	17.37
15-44	1398000	44.98	544000	17.50	1942000	62.48
45-64	252000	8.11	68000	2.19	320000	10.30
65-79	15000	0.48	12000	0.38	27000	0.87
80	3000	0.10	3000	0.10	6000	0.19
Total	2092000	67.31	1016000	32.69	3108000	100.00

Source: Compiled from Ministry of Economy & Ministry of Health Websites

Table 7-5: Population by Age and Gender UAE – Source Yeboah, D.A., (2007), Impact of population variables on health services demand in the United Arab Emirates, Arab Studies Quarterly, available at:

http://findarticles.com/p/articles/mi_m2501/is_1_29/ai_n27223614/?tag=content

Table 7-5 shows that only 19.7% of the working population in the UAE (15-64 years) is female with 54% being male. This would explain why only 36.8% of the population of M2 are female as compared with 67% in building M1 which is in Christchurch, NZ. The fitness profile of the population in each building based on BMI which is supported by Booth et al (2002) is reflected in M1 where 19.2% of the population is obese and in M2 it is 17.9%. The pattern is therefore similar. The level of functional limitations for M1 and M2 are 17.2% and 18% being obese with an associated metabolic health condition. The lack of fitness is therefore similar between buildings.

The most prevalent condition in M1 and M2 is asthma/ dyspnoea (11.4% and 7.9%) followed closely by reduced mobility (8.6% and 5.7%). It is doubtful that these two conditions would be combined to the extent that the overall percentage of the population with these two conditions would exceed 2%. It is interesting to note that two cognitive conditions comprising fear of falling and fear of crowds only constitute 2.9% and 0.7% for M1 and M2, respectively. Statistically these are two possible outlier conditions[184] and yet two falls occurred in M2 during the trial evacuation. These falls will be reported in a subsequent section. Reduced vision features reasonably well at 4.8% for M1 and 4.3% for M2. The reasons attributed for the falls was lack of strength for one fall and a cardio vascular condition for the second. The person in each fall had a BMI > 30. The definition of fall in each incident satisfied that of Tinetti et al (1988) where the person involved came to rest on the ground. The impact of the distance traversed is interesting when comparing M1 and M2. The impact of distance can be best described by the distribution of the participants according to the floor from which they started their evacuation. An examination of Table 7-1 for all those located on a level that would involve traversing more than 10 storeys constitute 57.9% of the respondents for M2. Similarly a calculation from Table 7-1 shows that 37.7% of the respondents traversed more than 20 storeys. This impact shows up in the pattern set up between M1 and M2 for those who responded by strongly agreeing with the question of how they "felt" after the evacuation. Table 7-4 shows up this pattern. 25.7% of the population in M2 as

[184] Less than 5% of the population is taken to be an outlier when compared with the rest of the population where there is no fear of falling. Fear of falling would have a potential for falling.

compared with 2.9% in M1 had soreness in the lower leg or knee on completion of the evacuation. 21.2% of the population in M2 compared with 1.0% in M1 felt dizzy after the evacuation and 16.7% of M2 compared to 1.0% of M1 had problems breathing. Discomfort in the chest was 10% for M2 and there no instances of this condition in M1. Finally 23.1% of the population in M2 were fatigued as compared with 1.0% in M1. There is a need to further study the correlation matrix to establish whether there is a significant relationship between distance and its impact on individuals. Pattern matching shows significance.

Buildings M3 and M4

The intrinsic characteristic profile of the populations in Buildings M3 and M4 are shown in Table 7-2. There is a similarity between M3 (UK) and M4 (NZ) in terms of the percentage of the amount of mature age office workers (28.8% vs. 32.3%). The NZ figure actually agrees with the projected rate for the UK whilst the UK rate is slightly below. If the mature age office worker is defined as being 40 years plus then the raw data shows that M3 and M4 are equivalent. The proportion between male and female are basically the same for M3 and M4 and follow the same pattern for M1. The split for M2 is therefore due to culture as explained in the previous sections. Gender is not a significant factor in terms of the identification of descent speed as shown by Peacock et al (2009). This finding is based on a multivariate regression using aggregated data from a number of buildings. This is also found to be the case in this PhD Study using pattern analysis of the correlation between buildings M1 to M6.

The next set of intrinsic core consistency characteristics to be analysed are the functional limitations or health conditions (see Table 7-3). There is some similarity between the two buildings except for:

- Asthma/ dyspnoea (M4=12.4% and M3=3.7%
- Reduced mobility (M3=11.2% and M4=8.3%)

- Reduced hearing (M4=7.3% and M3= 2.7%)
- Reduced vision (M4=12.4% and M3=5.6%)
- Fear of falling (M4=13.4% and M3=2.8%) where the difference is most marked out of all the variables.

Other possible critical conditions are balance and obesity with a health condition (M3=22.4% and M4=30.2%), A qualitative conclusion that could be drawn here based on Al-Abdulwahab (1999) and Ayis et al (2007) is that this would be reflected in the distribution of results showing the impact of the actual descent relating collectively to fatigue amongst other issues.

Comparing the apparent relationship between the two parts of Table 7-4 being "perception of the stairs", highlighted in pink and the conditions of the respondents after the evacuation, the following comments can be made:

- Dizzy condition relates possibly to balance in health conditions as it could relate also to fatigue (7.8/9.6% M3 and 0.7/3.1%M4). Other conditions such as dyspnoea and fatigue could contribute.
- Sore lower leg relates to reduced mobility and arthritis in the lower leg (knees) (12.4/6.7% M3 and 7.8/9.3% M4).
- Dyspnoea and asthma could also relate to chest discomfort. The comparison will be made directly with asthma/dyspnoea (11.4/9.7% M3 and 7.9/1.0% M4).

There is a pattern for vestibular and fitness conditions but this disappears for M4 for aerobic capacity. The reported level of fitness for M4 is less than M3 and yet this is not reflected in M4 results in Table 7-2. There does not appear to be any difference from M3 even with the increased distance traversed for the occupants of M4 of 31.1% of the population who responded being located above the 20th

floor and with over 45% of that population being located on the 23rd floor (Table 7-1).

Table 7-3 shows that on the whole Building M4 is estimated by occupants to be far less crowded than M3 (97.9% as opposed to 81.9% especially when 30.2% of the M4 population said that they were alone in the stairs). Observer's comments do not enhance the issue so that drawing any conclusions could be difficult especially when over 31.1% of the population were located above the 20th floor. Perhaps there were more opportunities for people to rest without having to deal with group embarrassment (See Focus Group Conclusions in Chapter 6).

Buildings M5 and M6

The intrinsic characteristics of the M5 and M6 populations are shown in Table 7-2 above. Mature office workers comprise above 30% of the workers in M5 and M6 which is within the representative range predicted for the UK (Dixon, 2003). The level of functional limitations represented by the level of obesity and number of health conditions are 25.8% for M5 and 20.6% for M6 and yet the level of fitness is high for M5 and moderate for M6 using the scales recommended by Sjostrom et al (2005). It is expected that there will be some differences in the distribution of responses for this Cycle.

Table 7-1 shows that 34% of the occupants in M6 are located above the 23rd floor so that this may well show up in the impact of the increased distance on the occupants especially given the difference in the level of fitness in M6 (Obesity is 14.6% for M6 as compared with 11.7% for M5. The stairs in each building involve four turns per storey and each have a 500mm+ open well extending full height of each stairwell.

The highest levels of responses for M5 are grouped on floor numbers 6, 8, 9-10, 14 and 16. They are evenly distributed in M6 with the largest group being located on level 8. There are marked similarities in the descent experience in each of these buildings and yet responses may be influenced by distance traversed as well as by the recorded functional limitations.

Table 7-3 will be discussed for this cycle given the physical similarity between the stairs and the population with 25.8% of the population for M5 having one health condition and 20.6% for M6. 13% of M5 have two or more health conditions as opposed to 7.7% for M6. It can be argued that the responses above would reflect a higher degree of impact for M5 than M6. This is not the case as will be discussed in the next paragraph.

The overall impact appears to relate to the increased distance that was traversed by 34% of the M6 population who were located above the 23rd floor. This is supported by the following (Table 7-3 and Table 7-4):

- 21% of M6 as compared with 7% of M5 had sore lower legs and knees even although 10.4% of M5 had reduced mobility compared with M6. 5.2% of M5 had arthritis as compared with 2.9% of M6.

- 15.5% of M5 had asthma or dyspnoea as compared with 9.4% of M6 and yet only 3.4% of M5 responded any problems as compared with 11% for M6. Distance traversed can account for this.

- 26% of the M6 occupants stated that they were dizzy after going down the stairs whereas only 6.8% of M5 stated that they suffered any after effects. This cannot be explained by postural problems, reduced vision or a combination of functional limitations. It may be explained by fatigue where only 4.8% of M5 as compared with 14.5% of M6/ This is supported indirectly Table 7-3 by Al-Abdulwahab (1999) and also by Parijat (2006) in a study of the effects of lower limb fatigue on the outcome of falls. One of the M6 stairs was also the site for one of the reported falls which it was claimed was due to vertigo or dizziness. It should also be noted that the mean level of fitness for M6 was some 40% less than M5 (measured in METS min/week).

Distance traversed therefore plays an important part and will be studied further in the section on correlations[185]. It should also be noted that stair descent speed in M5 was most likely reduced because of density[186] (perhaps some "platooning") where 74% of the occupants stated that the stair was very crowded and moving slowly as compared with. 76% of M6 stated that the stair was crowded but moving quickly (Table 7-3).

7.2.3 The STAIRS – Descriptive Statistics

Buildings M1 and M2

Table 7-4 compares buildings M1 and M2 in terms of how the building occupants estimated the construction and environment of the STAIRS on completion of the evacuation. The slope of the M1 stairs is 34.5^0 and 30^0 in M2. M1 has a single handrail and M2 two ungraspable handrails (60mm dia.)[187]. The level of illumination was similar but nosings were more legible in M1. The responses did not match the observations.

The occupants of both buildings found the handrails easy to access and grasp (88.1% for M1 and 95.3% for M2). This pattern was not the same for the sighting, use and uniformity of the steps where on average 75% of the M2 occupants found were satisfied as opposed to 49% of the M1 occupants. It should be noted however that 37% of M1 occupants were neutral on the issues as compared with average of 9% for M2. The visual images of M2 show a lack of contrast between all of the elements whereas those of M2 show a lower level of illumination.

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[185] It is already seen as an important determinant of overall descent speed (Peacock et al, 2009) and in relation to the associated impact of functional limitations by Ayis et al (2007)

[186] Shown in Section 7.6 to be due to density from checking with video results.

[187] 40mm set as the limit ergonomically and also see Aldersen (2010). Possible that merely running their hand along the surface of the handrail was sufficient as shown by Reeves et al (2008a)

48.5% of the M2 occupants compared to 20.8% of the M1 occupants estimated that the stairs in M2 were too steep. Even the treads in M2 were wider (300mm) as compared with M1 (270-285mm). This was not reflected in the occupants' perceptions where 26.7% of the M1 occupants thought the treads were too narrow as compared with 47.5% of the M2 occupants where the treads were wider. It is interesting to note that 78.8% of the shoe size worn by the M1 population was less than 8.25 UK and less than 8.3 UK for 70% of the M2 population. It would appear therefore that once again the distance traversed would have made the difference when viewed in the context of Table 7-4 above.

Buildings M3 and M4

The stairs for M4 are scissor stairs comprising two flights in one run with an intermediate landing per storey with approximately ten steps per flight. The clear width between handrails is 1000mm and there are two 40mm diameter handrails at 900mm. The treads are 260mm wide and the risers 150mm high. The slope is some 30^0. The steps and handrails are reasonably well defined.

There are two stairs in the M3 building one known as the "clean stair" which is carpeted with a dark brown carpet providing a contrast with the surrounding white walls. The steps are defined by aluminium nosings but the treads are only 245mm wide. Support is provided by a single square section handrail (35mm square) where the user's grasp is broken by continuous vertical supports. Risers are 190mm high. The other stair is known as the "dirty stair" comprising an off form concrete environment. The treads are 250mm wide and the risers 190mm in height. The handrail is a square section as before and is painted red. The nosing of each step is marked with a contrasting yellow stripe. The level of illumination is approximately 100 lux. The gradient of the steps is 37^0.

The legibility, uniformity and construction of each flight are virtually the same for each building. The gradient for M4 is less than M3. Table 7-4 shows that 92.4% of M3 and 96.9% of M4 respondents found the handrails easily. 92.3% of M3 and 97.9% of M4 respondents found the first step in each flight easily and this response was consistent for uniformity and turning at the last step in each flight. Only 25.8% of M3 found the treads too narrow as compared with 20.6% for M4. The fact that 57% of the respondents for M3 wore shoes 8.5UK and less and that 67% and less of M4 occupants wore size 9.0UK shoes does not appear to account for the difference in the responses. The responses follow the same pattern as M1 and M2.

23.1% of the occupants of M3 found that the stairs were too steep and 9.3% of M4 found that they were too steep. The difference of 7^0 may in fact be significant. The impact was recorded in Table 7-4, where the steepness could have accounted for the increased dizziness, sore lower legs and knees, and fatigue. It does not reflect the increased incidence of the fear of falling which amounted to 13.4% of the respondents. This same proportion did not increase the rate of 9.3% who thought that the stairs were too steep so that 30^0 must be satisfactory. This is supported by Figure 7- 5 where 30^0 falls within the preferred zone.

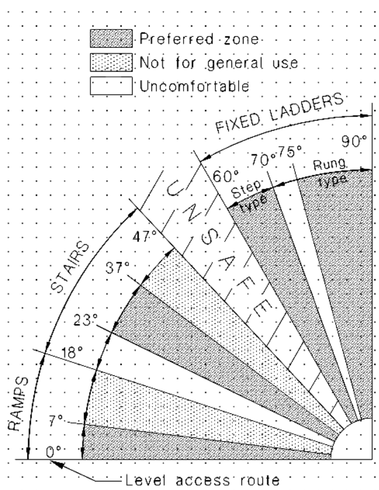


Figure 7- 5: Figure of stair gradients from D1/AS1 (DBH, 2011)

Buildings M5 and M6

The configuration of the stairs from each of these buildings incorporate three intermediate landings which result in four turns being made every storey. The test stairs for the Fuller Figure and Mature Age Worker Focus Groups studied in Chapter 6 were from M6. They mentioned that the increased number of turns made them feel dizzy along in association with the distance traversed. They said that the dizzy feeling was triggered by the constant "downwards spiral"[188]. The slope of the M5 stair is 33^0 and 37.2^0 for M6. The width of the treads for M6 is 250mm as compared with 270mm for M5. M5 has open treads which are contrary to most building codes. The level of illumination is in excess of 100 lux for M5 and M6.

The handrail for M5 is a rectangular timber section which is not graspable[189] as compared with M6 which is circular and graspable. The steps in M6 are less conspicuous than M5. Table 7-4 shows how the occupants estimated the stairs during their evacuation. A view of the M5 stairs is included at this stage for reference in Figure 7-6.

Figure 7-6: M5 Stair - open risers

[188] Downwards spiral increases with the number of turns per storey and M6 had 3 times as many as M5.

[189] Rectangular dimensions preclude a full circling by the hand and is not suitable to prevent a fall (Alderson, 2010)

It will be interesting to see whether or not the open risers distracted the occupants as they went down the stairs.

An analysis of Table 7-4 reveals the following:

- The observed differences in the handrail types and their conspicuity did not trigger any marked differences in response with over 80% of the occupants in each building recording their general satisfaction.
- There were no real issues with the legibility and configuration recorded in that an average of over 90% of the occupants was satisfied.
- Small treads were an issue for M6 where 31% of the occupants were concerned as compared with 18.9% in M5. This is interesting where 50% in each building required a 285mm tread to accommodate their feet facing front on. In terms of M6 the overhang of 50% of the occupants' feet would exceed 10mm. This may support the 31% response from M6. One of the members of the larger figure focus group with size 10+UK shoes confirmed that he "minced' down the stairs.
- The gradient of the stairs was certainly an issue. 28% of the M6 occupants as opposed to 10.3% of the M5 occupants thought that the stairs were too steep. There is an increase in gradient of the M6 stairs over the M5 stairs by some 4.2^0, but it is highly unlikely that this would have triggered the increased perception. It is more likely that the perception was reinforced by the narrow treads and the increased distance traversed.
- Distance, as reflected in the question "there were too many flights", was also an issue. 30% of the M6 occupants agreed that there were too

many flights which can be directly attributed to distance since 34% of the occupants evacuated from above the 23rd floor.

7.2.4 You and Others (Group)

Buildings M1 and M2

Table 7-3 shows that 79.5% of the occupants in M2 as compared with 31.4% in M1 formed groups prior to entering the stairs. This may be due to a difference in cultures[190] or office layouts even with 63% of the population in M2 being male and only some 36% in M1. The evacuation of M1 was rapid and occupants were used to the exercise and therefore group formation may not have been important. Groups were formed according to the work location which shows that in aggregate some 54% of the M2 occupants were involved as compared with some 20% in M1.

It could be argued that it was the scale of the space provided by the degree of internal subdivision of the floor plate (four strata units per level) on each level and ownership of the office space that dictated this. Wineman and Adhya (2007) support this due to the estimated degree of privacy, the increased degree of connectivity and most likely a greater awareness of organisational issues. The floor space in M1 was not subdivided to the same degree; the organisations were much larger in size and in some cases occupied a number of consecutive floors. Another possibility is the influence of management and their evacuation procedures. The occupants of M1 were more likely to be familiar with trial evacuations and their awareness of the short duration involved so that they did not see the need to evacuate with their friends to the same degree as M2. The evacuation time for M2 was also four times that of M1 and amounted to double the distance.

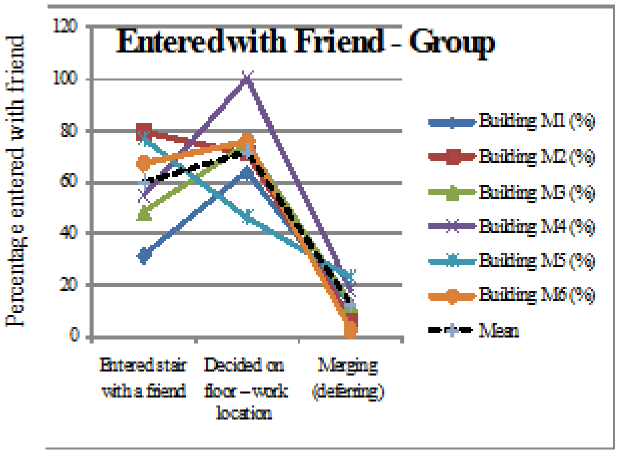
[190] Purely an observation raised by more than one observer who were all expatriate.

The degree of voluntary merging basically followed the same pattern in M1 and M2 indicating that the occupants were either "told" by the fire wardens to wait their turn or did not have any need to merge because of the sequencing of the evacuation. This is discussed further under "*Management – M1-M2"*.

Buildings M3 and M4

Building M3 and M4 had similar floor plate subdivisions and types of organisations so that according to Wineman and Adhya (2007) group formation as influenced by the work setting and conditions should be similar for each building. M3 is located in the UK and M4 in New Zealand

Buildings M3 and M4 are similar in terms of the group numbers entering the stairs being 48.1% and 54.7% respectively (Table 7-3). There is a difference in where the groups were formed being 74.5% for M3 and 100% for M4. The percentages that formed the groups still show the influence of working space and conditions (Wineman and Adhya, 2007). Figure 7-7 shows a similar pattern for all buildings for where the groups were formed except for Building M5. Across all the PDSA Cycles M3 and M4 are close to the "mean" for the percentage entering. M3 coincides with the mean in terms of where the groups were formed whilst M4 stands apart from the remainder by some 25%. This difference cannot be explained other than it still fits in with the pattern of the remaining buildings other than Building M5. Voluntary merging for the two buildings is similar and follows the general pattern for all buildings (M3=12.4% and M4=17.9%). This will be further compared with the influence of Management and Procedures in the section, "*Management – Buildings M3 and M4"*



Plots are for categorical data and clearly indicated in symbol format. The linking together of the symbols is to indicate the pattern of each group of responses for the purposes of pattern matching. (Hak and Dul, 2009)

Figure 7-7: Graph of Group formation M1-M6 for pattern matching comparison

Building M5 and M6

The floor plates for M5 and M6 are rectangular in shape with a length to width ratio of approximately 3.5 to 1 for M5 and 2.5 to 1 for M6. M5 accommodates a large government department and M6 a large banking organisation. The orientation of the floor plate for M5 interfered with the connectivity (Wineman and Adhya, 2007) between work groups on each floor whilst in M6 this connectivity was less. Also this core consistency would have been strongly influenced by the Evacuation Strategy for both M5 and M6. In M5 the evacuation strategy was for an "uncontrolled" (one-out, all-out) sequence whilst in M6 the procedure was for a sequential evacuation where floors evacuated in groups of three with each floor using a designated stair. M6 involved a greater degree of interface between occupants and fire wardens whilst in M5 everyone just responded automatically to a single alarm and headed straight for the stairs. The difference in spatial conditions and evacuation organisation/management is most likely responsible for where the groups were formed by 46.2% of people in M5 in their work location as compared with 75.9% for M6 (Table 7-3).

Merging was marked in M5 because of the size of the population all entering the stairs at approximately the same time. 22.8% of the population in M5 queued before entering the stairs and voluntarily merged with others as compared to 2.4% in M6 due to the staggered stair entry times. The extent of grouping in the stairs was similar for M5 and M6 (76.7% and 67.3%).

The pattern of responses for this core consistency is inconsistent for M5 (see Figure 7-7) based on the high rate of group formation prior to entering the stairs, the fact that the groups did not relate to the work location to the same degree as the other building and also that the extent of merging was marginally higher than for others. The difference is also most likely due to the impact of "Management".

7.2.5 Management and Maintenance – Statistical Analysis

Buildings M1 and M2

Table 7-3 indicates that 11.9% of the population for M1 and 6.4% for M2 voluntarily deferred to others coming down the stairs as opposed to 16.8% (M1) and 17.4% (M2) who were instructed to do so by fire wardens or as part of their procedures. Some limited merging did occur because of the limited extent of queuing shown in the same table.

The pattern of evacuation experience and its impact on group formation and compliance with procedures is indicated in the difference between the responses for M1 and M2 where M1 exceeds M2 by some 52.3% for evacuation experience and 50 % in terms of the use of a stair designated in the procedures. Feedback from the observers indicated that M2 occupants were not really aware in detail about what they were expected and had committed to do. Table 7-1 indicates the number of floors where occupants used lifts in lieu of the stairs. This was most likely as a result of the extreme 40^{0}C+ temperatures and the failure of the stair ventilation systems (see also results of 1977 Canadian Study in Chapter 5).

Buildings M3 and M4

Table 7-3 shows that 81.9% of the M3 population and 97.9% of the M4 population paint a picture of a sparsely populated stairwell. Both M3 and M4 held regular evacuation drills once or twice per annum and this is confirmed by 72% of the respondents from M3 and 83.3% from M4. This is well in excess of Building M2 (33.3%) and is similar to M1 (85.6%). It would also appear that the occupants were familiar with their stairs as 83% from M3 and 81.8% from M4 used their designated stair showing a similar influence as for M1 and a difference for M2 (little evacuation experience). The percentages of occupants in each building waiting for people to pass under instructions from fire wardens and also as a result of organised queuing totalled 16.2% for M3 and 29.4% for M4 which is shown to be of the same "order" from the responses in Table 7-3 above where the stairwell is estimated as being sparsely populated.

No substantiated explanation can be given for the apparent difference in the location of group formation for building M4 so that it could quite well be other spatial and working condition factors such as those mentioned by Wineman and Adhya (2007) for which additional tenant information would be required and which could not be made available as the result of the agreement with the building owners.

Buildings M5 and M6

The impact of management on the trial evacuations for M5 and M6 is shown in Table 7-3. 23.5% of M6 (M5=3.5%) queued before entering the stairs. This was generated by the fire wardens who only allowed the occupants to evacuate at set times because of the sequential or phased evacuation strategy. The 19.3% of the M5 population (M6=2.4%) who waited for people to pass deferred as part of the practised procedure. The previous claim of prior evacuation experience is supported by the 83% and 85% response rates for M5 and M6[191] respectively and by the high response rates for the use of the designated stair.

It is interesting to note that the Fuller Figure and Mature Age Focus Groups commented on the test stairs in M6 stating that there was no colour contrast between each steps in the stairs and also between the handrails and the surrounding walls. The standard of maintenance in M6 was high and when Management heard about the comments of the "white-out" conditions in the stairs they improved the situation by marking the nosings.

7.3 Relationships drawn from Correlations

The correlations for M1-M6 are presented together as the correlation matrices are preceded by factor analysis using aggregated data.

The following schedules are included:

- Factor analysis for health conditions/ functional limitations / including those after descent
- Factor analysis of STAIRS
- Combined factor analysis for STAIRS and the Individuals' functional limitations
- Correlation matrices.

The factor analysis related to the stairs and the functional limitations that appeared as a result of the completion of the stair descent task. The correlation matrices in Table 7-9 and Table 7-11 showed highly significant correlations between all the "STAIR" factors and the functional limitations for all six buildings. These relationships could then be generalised across the cases and provide the argument for aggregation ready for factor analysis. It

[191] M6 could quite easily be challenged and most likely refers to previous experience.

was also necessary to isolate out that those functional limitations or health conditions that related directly to stair descent and compare them with the other self reported health conditions from the questionnaire in the Appendix A3.

Variable	Component	
	1(7.8)*	2(4)*
handrail easy to find		.948
first step easy to find		.970
each step easy to find		.972
last step easy to find		.970
stair gradient	.839	
treads too small	.826	
too many flights of stairs	.881	
soreness in lower leg	.653	
dizziness after descent	.925	
out of breath after evac	.930	
chest discomfort	.928	
sore knees	.906	
worn out	.915	

Table 7-6: STAIR Perception and Impact Factor Analysis PDSA 2 and PDSA 3 Aggregated **Explains 83.9% of the variance; KMO .913; Eigenvalue are 7.8 for component (1) and 4.0 for component (2)s; Selection value for values highlighted in yellow ≥ 0.6 for all and 0.7 for STAIRS*[184].

Principal Component 1 *(Grouped as descent risk/ functional limitations)*

Principal Component 2 *(Grouped as visibility and support)*

Table 7- 6: Stair Survey Response-- Factor Analysis

Variable	Component			
	1 Cognitive /Neurological	2 Metabolic/Cardio	3 Spatial awareness/ orientation	4 Mobility/ Lower limb pain
a) Heart condition		.482		
b) Asthma or breathing diff.	.255			
c) Prior stroke		.680		
d) Type 2 diabetes		.770		
e) Balance	.711			
f) Arthritis				.684
g) Reduced mobility				.615
h) Injury so no walk quickly				.711
i) Hearing loss or reduced hearing			.790	
j) Reduced vision			.605	
k) Loss of memory		.572		
l) Fear of falling	.681			
m) Fear of crowds	.709			

Selection values ≥0.7 drop (a), (b), (c), (f), (g), (j), (k), and (l)
Selection values ≥0.6 and ≤ 0.69 drop (a), (b), and (k)
Selection values > 0.5 capture all health conditions except for asthma/ dyspnoea which changes when coupled with stair descent impact question.
KMO = 0.83, Variance 53%, Eigenvalues > 1 and selection values as noted above

Table 7-7: Factor Analysis Output for Health Conditions / Functional Limitations

	Cardio-vascular and Vision					Mobility/ Pain				Posture/ Stability			Stair visibility				Descent Risk								
Variable → / Component ↓	Heart Condition	Asthma or dyspnoea	Prior stroke	Type 2 diabetes	Balance	Arthritis	Reduced Mobility / injury	Reduced hearing	Reduced vision	Loss of memory	Fear of falling	Fear of crowds	Handrail easy to find	First step easy to find	Each step easy to find	Last step easy to find	Stair gradient	Treads too small	Too many flights – downward spiral	Soreness in lower leg	Dizziness after descent	Dyspnoea after descent	Chest discomfort	Sore knees	fatigue
1.																	.85	.84	.89	.7	.93	.94	.94	.91	.92
2													.93	.95	.95	.95									
3						.7	.75																		
4								.8		.7															
5					.51						.77	.67													
6	.65		.67	.67																					
7		.8							.50																

All component eigenvalues > 1 and selection values > 0.7 except with lower cut-off at 0.5; KMO = 0.84 and Variance = 73%

Table 7- 8: Combined Factor Analysis Output

Variable	*Designated stair*	*Stair friend*	*Condition on stair*	*Fatigue/ tired*	*Too many flights*	*Handrail easy to find*	*First step easy*	*Each step easy*	*Last step easy*	*Stair too steep*	*Treads too narrow*	*Stair confidence*	*Storeys can cope with without a rest*
Designated stair		*3*		*3**	*2*								
Stair friend				*3*									
Conditions on Stair						*3*	*(3)*	*(3)**	*(3)**		*(3) (5)*		
Fatigue/ tired					*1**2**3**4***	*(1*)(3)*(4)*	*(3)*	*(3)*	*(3)*	*2**	*2**4*	*1 5*	
Too many flights	*2*		*3*	*1**2**3 4***		*(3)**5***	*(3)**5*	*2(3)**5*	*(2)*(3)(4)5***	*3**4***	*3**4***	*1*	*4*
Handrail easy to find			*(3)*	*(1)*(4)*	*(3)*5***		*(3)*4**5***	*1 2**3**4 5***	*2**3**4** 5***	*(3)5**	*(4)*		
First step easy			*(3)**	*(3)*	*(3)*	*1*2**(3)**4** 5***		*1**2**3***4** 5***	*1**2**3**4** 5***	*(3)**(4)**5***	*(1)**(3)**(4)** 5*	*(4)***	*5*
Each step easy			*(3)**	*(3)*	*2(3)*5*	*1 2**3**4** 5***	*1**2**3**4** 5***		*1**2**3**4***	*(3)**(4)** 5**	*(1)(2)(3)**(4)***	*(3)(4)**	*5*
Last step easy			*(3)**	*(3)***	*2(3)**(4)5***	*2*3**4** 5***	*1**2**3**4** 5***	*1**2**3**4** 5***		*2**(3)**(4)** 5*	*2(3)**(4)***	*(3)(4)**	*2*
Stair too steep				*1 2*	*2**4***	*5***	*(4)*5*	*2(4)**5**	*2*(4)**		*1 2**4**5***	*1***	*4*
Treads too narrow		*5*	*3*	*2**4*	*1**2**3**4***	*(3)**(4)*	*(1)*(3)**(4)** 5*	*(1)*(3)**(4)***	*2(3)**(4)***	*2**3**4** 5***		*1***	
Stair confidence			*5**	*2 3*	*1*		*(4)***	*(4)***	*(4)***	*1***	*1***		*1*4 6**
Storeys can cope without a rest No rest				*4*	*4*		*5*		*2 3*	*4*		*1*4 6**	

*** p<.001; *p<.01; no superscript = p≤ .05 All R's >0.2 / All M5 relationships are significant for M6.* *All buildings (100%)* *60% all buildings* *50% all buildings*

Table 7- 9: Correlation Matrix for "STAIR" Survey Variable

Variable	too many flights	sore lower leg	dizzy/descent	dyspnoea	chest discom	fatigue general	fatiguewalking	falls history	fear of falling	fear of crowds	no.health cond.	Age	Gender	BMI	Mets
Sore lower leg	1**,2**3, 4**5**		1**,2**3**4**5**	1**,2**3**4*5**	1**,2**3**4**5	1**,2**3**4**5**		(1)**,(3)	(5)*	(3)*	(1)**,(2)*(3)(5)*	(3),		(1),(3)*(4)*	(1),(3)*(4)*
dizzy/descent	1**,2**3** 4**	1**,2**4**5**		1**,2**3**4**5**	1**,2**3**4**5**	1**,2**3**4**5**		(1)**,(3)*	(1)**,(3)*	(1)**,(3)*5	(1)**,(2)*(3)*(5)*		2,	(1),(2)*(4)	(1),(2)(4)
dyspnoea	1**,2**3** 4*5**	1**,2**3,4**5**	1**,2**3**4**5**		1**,2**3**4**5*	1**,2**3**4**5**		(1)**,(2)*	(1)*,(3)*(5)**	(1)**,(3)*(5)*	(1)**,(2)**(3)*(5)**			(1),(2)(4)	(1)*,(2)*
chest discomfort	1**,2** 4**5	1**,2**4**5	1**,2**3**4**5**	1**,2**3**4**5**		1**,2**3**4**5**		(1)**,(2)	(5)**	(3)*(5)**	(1)**,(2)*(3)*(5)			(1),(5)	(1),
fatigue/general	1**,2**3*4**5**	1**,2**4**5**	1**,2**3**4**5**	1**,2**3**4**5**	1**,2**3**4**5**		5	(1)**,(2)	4		(1)**,(2)*(3)*			(1),(2)	(1)*,(2)*
fatigue/walking		5				5			5	5*	5				
Falls history	(3)*	1**,2**3*	(1)**(3)*	(1)*,(2)*	(1)**,(2)	(1)*,(2)			2**3**	2**3**	1*,2		2,4*	1,	1,2
fear of falling			(1)**,(3)*	(1)**,(3)*(5)**	(5)**		5	3**		1**,2**3**4,5**	1**,2**4**5**	2*,		3*	1*,2,3
fear of crowds	(5),		(1)**,(3)*(5)*	(1)**,(3)*(5)*	(3)*(5)**		5*	2**,3**	1**,2**3**4		1**,2**4** 5**	2*,		3	1*,2 ,3**
too many flights		1**,2**3*5**	1**,2** 4**	1**,2** 4*5**	1**,2**5*,	1**,2**3*5**		2**3*		4,5	3				
no. health conditions	(1)*,(2)*(3)(5)**	(1)*,(2)*(3)(5)**	(1)**,(2)*(3)(5)**	(1)**,(2)**(3)*(5)**	(1)**,(2)*(3)*	(1)**,(2)*(3)*	5	1*,2*3*	1**,2**3**4**5**	1**,2**3**4**5**				1,	1,2
Age									2*3	2*	3**		(2)(3)	3	3*
Gender			(2),					2,4*				(2),(3)			
BMI	4*	(3)*(4)	(1)**,(2)*(4)	(1)**,(2)(4)	(5),	(2),(4)			1,3	1,3	1**	3			1**,2**3**4**5**
Mets	1, 4*	(1)*,(3)*(4)*	(1)**(2)(4)	(1)**,(2)*(4)	(1)**,	(1),(2)*		1,2	1,2,3**	1,2,3,4	1**,2**3**4**5	3*		1**,2**3**4**5**	

*All correlations > 0.2 ; **p ≤ .001; *p ≤ .01; otherwise p ≤ .05*

Legend: *All buildings across PDSA 1-3* · *60% buildings across PDSA1-3* · *50% buildings any PDSA Cycle*

1,2,3,4,5 = Buildings M1-M6 with M5 and M6 being aggregated

Table 7- 10: Correlation Matrix for Individual and Individual/Stair/Group

- 1-1: Generally tired and conditions in stairs: M1/M2 not significant/ M3/M4 not significant; M5 (r=0.38 and p<.01) M6 (r=0.44 and p<.01)
- A-A: Designated stair and entered with friend: M1/M2 not significant; M3 (r=0.3 and p<.01) and M4 not significant. M5/M6 (r=0.35 and p<.01)
- B-B: Group and conditions in stairs: M1/M2 not significant; M3/M4 not significant; M5/M6 not significant
- *-*: Warden Instructions and Designated Stair M1-M6 (r=0.3 and p<.01)
- *-*: Entered with a Friend and where formed group M1-M6 (not significant)

Table 7- 11: Inter consistency relationships

7.3.1 Factor Analysis – Aggregated Data

In an attempt to reduce data for an improved view of relationships that may be significant an exploratory factor analysis of buildings M1-M6 is presented in Table 7-6 to Table 7-11 above. The analysis establishes the relationships between variables based on their correlations to see whether there are any themes, patterns or groupings that may appear. The method used is the *principal component analysis* as this method of factor analysis attempts to explain the maximum amount of variance using the minimum number of underlying factors (Hinton et al, 2005). The factors are named to summarise the grouping of variables they represent.

The factor analysis procedure establishes an *eigenvalue* for each factor (>1) so that the factor can explain a relationship as a single variable. As the differences between the *eigenvalues* tend towards 1, the amount of variance represented by each principal factor decreases. The minimum difference in variance is usually 5% of the dataset or set of variables.

SPSS V16 Principal Component Analysis is the one that is used with the following statistical inclusions:

- *Univariate correlation matrix with significance levels**
- *Kaiser-Meyer-Olkin test of sampling adequacy where the factor should exceed 0.7 for the analysis to be internally reliable.**
- *The Varimax rotation method is used to extract the data together with the number of iterations required for the data to converge to arrive at the factors they have produced.**
- *Selection values for each of the grouped variables where the cut-off value should optimally be > 0.7 and certainly not < 0.5.**

(As suggested by Hinton et al, 2005, pp. 340-354 together with the UK Delphi Group)*

The initial analysis attempts to explore the grouping of the impact of stair descent on the individual and those STAIR perception variables that relate to this impact. Table 7-6 shows the results. There are two principal components or factors that explain 83.9% of the variance in the set of variables analysed. The KMO test result is 0.93 (>0.7) and the selection values for the included variables are >0.6. Component 1 has an *eigenvalue* of 7.8 whilst the second component has a value of 4. The major principal component grouping is interesting as it includes the STAIR variables of "too many flights" (distance), small treads (foot placement and stance) and the pitch or gradient of the stairs together with their associated impacts which relate to functional limitations and fitness. The second component is totally comprised of STAIR issues:

- Visibility and uniformity of steps
- Reachability of handrails for support and guidance

The first component is named "Descent Hazard or Risk" as it deals with those factors contributing directly to falls being distance, tread width and pitch and the second "Visibility and Support" which relate to reachability of handrails and visibility of the steps. Table 7-7 attempts to reduce "health conditions" or "functional limitations" into a number of principal factors. The purpose of this is to compare the grouping of the self designated individual conditions with the variables listed in Table 7-6 above. It is interesting to note that the selection values for asthma fell well below 0.5 along with heart condition. Loss of memory also failed. Balance as a vestibular condition along with the cognitive variables of "fear of falling" and "fear of crowds" form the first principal component that are summarised as "Cognitive/ Neurological" conditions (Horak, 2006). The second major component includes "Metabolic" conditions as described by Booth et al (2002). The third component deals with reduced vision and hearing and therefore relates to orientation in the main. The fourth component deals exclusively with lower limb mobility. A comparison between the impact variables and the self designated health conditions show an agreement of 60% with expected exclusions being dyspnoea and fatigue. It could be argued that the latter "impacts" are more directly associated with the level of fitness than other health conditions.

Table 7-11 is a combined analysis of the entire data set and shows the "ordering" of the variable groups. The ordering is as follows:

- Component 1 – Descent Risk or Hazard
- Component 2 – Visibility and support
- Component 3 – Mobility
- Components 4/5 – Stability and Posture
- Component 6/7 – Metabolic (incl. reduced vision)

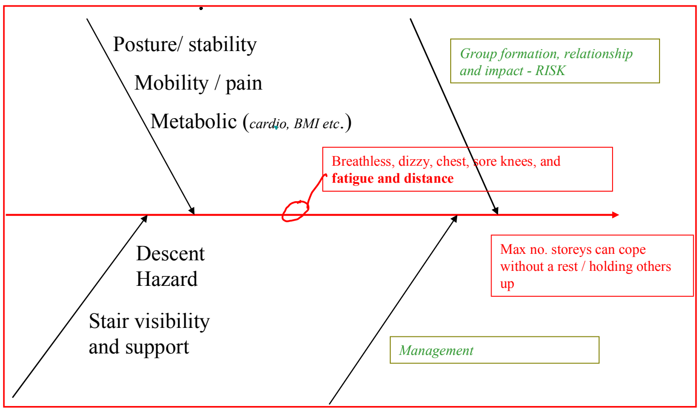


Figure 7-8: Ishikawa Chart of factor Analysis Results showing framework for satisfaction of Aim and Objectives

The STAIR factor of descent hazard is of special significance as it highlights one of the main comments made by the focus groups in Chapter 6 concerning the "ever continuing downward spiral". The coupling of "too many flights" with "steepness" provides this "feeling" of the downward spiral and that is directly connected with fear of falling and crowds. The latter are also grouped with balance. It is interesting to note that there is a pattern between the factor analysis of the survey data and the measured data in the intent of the major principal component which is concerned with descent risk. The variable with the highest selection value in the instance of the measured data is the riser height comparing with that of stair steepness in Table 7-6 above.

The Individual arm of fin of the Ishikawa Chart Model in Figure 7-8 shows the grouping of the functional limitations and after effects of stair descent as posture, mobility and metabolic condition. This grouping confirms the concern of the focus groups with the effect of the "continuous downwards spiral".

The spine of the Ishikawa Chart Model in Figure 7-8 is where the effect of the extrinsic stair characteristics on the individual going down those stairs is analysed. The text highlighted in red shows the effects as fatigue, dizziness, breathlessness, chest discomfort and pain in the lower limbs. Distance as reflected in "too many flights" can have an apparent impact on the estimated pitch of a flight of stairs as shown in the different responses for M1 and M2 in the previous section especially when the width of the treads in the M2 stairs is sufficient for the mean M2 foot. The action of the individual in going down the stairs actually pitches the individual concerned forwards (Reeves et al, 2008a) so that increased distance can reinforce the feeling of falling. This is also confirmed by the benchmark focus group analysis described in Chapter 6.

The other factors in the two extrinsic core consistencies of Management and the Group were not directly included in the analysis because they deal with what happens after the fall except for the situation where the evacuation strategy results in less dense occupation of the stairs so that descent speeds are higher. Individuals in the group situation may be too embarrassed to ask the group to slow down or to make allowance for their limitations in the planning of trial evacuations. They are still included in Figure 7-8 above for the following reasons:

- The advice received from the Delphi Group.

- The important association between altruism, the group and the individual with functional limitations as shown in the two content analysis case studies in Chapter 6. Adams and Galea (2010) show the number of individuals required to assist an obese individual who may have fallen. A similar example is shown in the Dwyer and Flynn (2004) Content Analysis in Chapter 6. The "plug" formed by the group assisting the individual may result in delays where the stairs are not wide enough for people to pass. This is the case in M1-M6 confirming the finding of Peacock et al (2009).

- The impact that a scenario developed from the BMI Benchmark Focus Group Test and survey from Chapter 6 where the average speed of a potential group would have decreased by some 31% in one instance and 51.7% in the other. The velocity/ density charts for M1-M6 (excluding M5) also confirm this.

- The impact that Management can have in the evacuation strategy they select for training. Responses from M5 individuals show that conditions in the stairs were extremely crowded. High densities and slower descent speeds can mask fatigue so that distance can have a reduced impact on after-effects such as fatigue, dizziness, and breathlessness (Galea et al, 2008).

The objectives of the PhD Case Study are to establish those contextual factors that play an important part in the safe descent of multiple flights of stairs for office workers. The pattern of these relationships is discussed for all Buildings (M1`-M6) in the next section.

7.3.2 Intra correlation relationships

The STAIR

Correlation matrix (Table 7- 10) confirms the grouping outcome achieved in the Factor Analysis (Table 7-6) where there is a reasonably significant relationship between all the variables dealing with visibility and support across all the buildings ($R>0.2$ and $p<.001$). This did not include the pitch of the stairs and the width of the treads. Significant relationships were found for M2-M6 between narrow treads and steep stairs confirming that narrow treads are associated with steep stairs in general terms confirming that the user finds difficulty with the placement of their feet and hence a front on stance and requires support because of the "continuous downward spiralling" effect of the pitch or gradient. This grouping is one of Risk. There are also significant relationships between distance (too many flights) and narrow treads for buildings M1-M4 as well as for narrow treads and steps legibility for M3 and M4 and M1 and M2 in part ($R>0.2$ and $p<.05$). Such a relationship has been confirmed in practice by Nagata (2006). There is a further significant relationship on an aggregated data basis for foot length and narrow treads ($R=0.35$ and $p<.01$) that matches the findings of Nagata (2006). The confirmation of Nagata's finding by the above correlation is interesting because it is an actual self reported measurement (shoe size) correlated with a perception of tread width which is an estimate.

The Individual

Correlation matrix Table 7-10 shows some interesting significant intra core consistency variable relationships which also agree with the grouping in the Factor Analysis in Table 7-6:

- Sore knees and lower legs with postural stability ($p<.001$)
- Postural stability and fatigue ($p<.001$)
- Out of breath and fatigue ($p<.001$)

- Chest discomfort and fatigue ($p<.001$)
- Estimated distance traversed correlates significantly with pain in the lower limbs, fatigue and breathlessness ($p<.001$)

p<.001 is highly significant

The R for the above relationships are all >0.25 across M1-M6. The level of significance is high. This sets up a pattern so that the above could be applied as a generalisation across most multi storey office buildings. It also reflects the findings of Bergland et al (2008). They generally do not correlate with age or gender[192]. A regression analysis across the aggregated data set where the dependent variable is an individual's fall history and the independent variables are described as health conditions are all moderately significant at $p<.05$ and $R^2=0.329$. This confirms that the variable number of health conditions could be considered to a certain degree in analysis. The "number of health conditions" as a computed variable correlates reasonably significantly with the fear of falling, the fear of crowds and pain in the lower limbs, for all buildings M1-M6. Also the "number of health conditions" correlates reasonably significantly for M1-M6, excluding M4, with breathlessness, sore lower limbs and postural stability which are the self reported impact variables resulting from stair descent.

The lack of a significant relationship between age and variables such as fitness could be challenged and therefore needs to be discussed further in the next two main sections on PDSA Cycles 2-3 (M3-M6). This was not the finding from the Mature Age Focus Group analysed in Chapter 6. The lack of correlation is, however, consistent from building to building. Aggregating the data for M1-M4 there is a reasonably significant relationship between BMI and Age ($R=.512$, $p<.01$).

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192 Peacock et al (2009) agrees with gender. Correlation with age is achieved with M2 ($p<.01$).

Count

		Body Mass Index							
		0	Underweight (<18.49)	Normal Weight (18.5-24.99)	Overweight (25-29.99)	Obese Class 1 (30-34.99)	Obese Class 2 (35-39.99)	Obese Class 3 (40+)	Total
Age	0	34	0	0	0	0	0	0	34
	0-20	0	0	0	0	1	0	0	1
	21-44	0	7	142	107	8	20	11	295
	45-64	0	2	33	31	11	11	3	91
	65-74	0	0	4	4	1	2	0	11
Total		34	9	179	142	21	33	14	432

Table 7-12: Cross tabulation of Age by Body Mass Index - Aggregated for M1-M4

Table 7-12 provides a view of the distribution of BMI associated with each age group. 27.4% of the aggregated mature age population has a BMI > 30 whilst the 21-44 year age group is 13.2%. There is a distinct pattern between the two groups shown in Table 7-12. There is no distinct pattern across M1-M6 in terms of each building. This could be explained by a potential finding that as the office building populations are combined that they more closely resemble a general population profile as shown in Chapter 2 (Dixon, 2003) even with the low percentage of mature workers in the UAE which is reflected in the M2 population profile shown in Table 7-5 above. There is a linkage between BMI and age as measured by the walking velocity (Hulens et al, 2003).

There are moderately significant relationships for 50% of the buildings between BMI and dizziness, and lower limb pain and breathlessness ($R>.15$ $p<.05$). Dizziness can be seen as one of the components of postural stability and the relationship between the latter and BMI is documented (Al-Abdulwahab, 1999). As the "number of health conditions" and BMI each correlate with age and that this is demonstrated by a walking velocity test (Hulens, 2003 and Spearpoint and MacLennan, 2012) a fitness variable was computed that reflected this relationship for buildings M1-M4 as a precursor to the METS variable based on the IPAQ Short Form Questionnaire for M5 and M6. BMI also correlates moderately significantly ($p<.05$) with the fear of falling and fear of crowds for 50% of the buildings.

Group and Management

The pattern of relationships for these two core-consistencies is:

- Not significant for the "Group"
- Reasonably significant between warden instructions/ evacuation procedures and designated stair for M1-M6 ($R = 0.3$ and $p < .01$)

The focus groups provided some further information about what they considered to be reasonably significant for Groups:

- Estimated pressure from group members on those members of the group who could not go down the stairs at the same speed to do so thereby increasing the risk of falling due to dizziness or fatigue.
- Pressure on Group members to physically look after those members who fell or were unable to negotiate the stairs because of lack of fitness or other health condition.

7.3.3 Inter- correlations for core consistency relationships

Table 7- 11 shows the following inter core-consistency relationships:

- "Conditions in stairs" (Management) and "Entered with a friend" – M1, M2 and M4 are not significant and are reasonably significant for M3, M5 and M6 ($R => 0.3$ and $p < .01$).
- Fatigue and Condition in stairs were only reasonably significant for M5 and M6 but in different ways. M5 indicated that as the density increased and the descent speed slowed that the level of fatigue decreased which agrees with Galea et al (2008). On the other hand M6 is the opposite. ($R > +0.4$ for M5 and -0.4 for M6, both being reasonably significant, $p < .01$).

- "Designated stair" and "entered with a friend" showed a reasonably significant relationship for M3, M5 and M6 showing the level of familiarity with evacuation procedures across groups in each building. M1, M2 and M4 appear not to have had the same level of familiarity.

- "STAIR" and "Individual" core consistencies correlated with a high level of significance ($p<.001$) for the estimated distance variable of "too many flights" with $R>0.4$ for M1-M6 with those of pain in the lower limbs, breathlessness and fatigue and dizziness and chest discomfort for M1-M4 and M1-M3 and M5 respectively. This finding also agrees with the outcome of the overall aggregated factor analysis described in Table 7-8.

7.3.4 Further discussion of correlations

The variables of fatigue and the group of health conditions do appear to correlate reasonably well with distance (lower limb pain and breathlessness / asthma). When the number of occupant health conditions is combined with their BMI classification as indicated in the Factor Analysis there is no resultant improvement in the correlation with distance (too many flights) although some literature would suggest otherwise (Verghese et al, 2008; and Spearpoint and MacLennan, 2012). Shields et al (2009) may present a counter argument where evacuees with self-designated functional limitations in the WTC 9/11 incident were able to cope reasonably well with the distance. This may have been due to the masking effect of density (Galea et al, 2008)[193] where the reduction in descent speed allowed the evacuees to adopt a more considered stance and even

[193] Dwyer and Flynn (2004) report many people resting. Galea et al (2011) and Spearpoint and MacLennan (2012) also conclude the same reason. Survival in a real situation may dictate "pushing through the pain" but this conclusion is not extensively documented. The PhD study is focussed on trial evacuations.

rest during merging delays. Even the inclusion of a stair confidence measure in the questionnaire for M3 and M4 did not improve the situation.

It should also be noted at this stage that the Results have not included the two falls in the M2 evacuation. These will be analysed and discussed further in a later section as they are considered to be outliers especially when converted into a rate of falls per number of flight uses. Also the level of falling risk extrapolated by the author from Johnson and Pauls (2011) falls off rapidly for tread sizes of 250mm +. Tread sizes vary from 245mm in M1 to 300mm in M2 so that any record of observed falls is extremely important (MacLennan et al, 2011). The further analysis of the falls is important because of highly significant recorded relationships between fatigue and balance ($p<.001$) (Tiedeman et al, 2007 and Samy and Hamid, 2010). Fitness also relates to fatigue and strength (Booth et al, 2002).

7.4 2008-2010 Case Study Survey Results and Discussion – Risk of Falls and Estimated Descent Capability.

7.4.1 Incorporation of falling risk measures

Further to the discussion in Chapter 6 there is a decrease in risk of only .012 for treads between 250mm and 300mm wide as compared with 0.14 for widths between 195mm and 245mm (Wright and Roys, 2008 and Johnson and Pauls, 2011). Further analysis of the above reveals a natural log relationship of *y (width of tread) =-35.03ln(x) +144.73 and x = level of risk)*. If a logarithmic scale is used on the x axis there is a relatively even distribution of data around the linear plot[194] ($R^2 = 0.88$ and $p<.01$ – reasonably significant).

The risk of falling for the range of tread widths for M1-M6 is extremely low. Roys (2006) and also MacLennan (2011b) showed in separate studies that the mean size of the male foot was some 300mm. Table 7-13 shows that the observed foot placement and stance risk is highest for M3 and M6 followed by

[194] See Chapter 6

M1, M4 and M5. This is not reflected in Table 7-4 from the survey where the order is M2, M6, M1, M3, M4 and M5. Roys (2006) and Johnson and Pauls (2011) rate tread size as the major determinant of falls. Johnson and Pauls (2011) do however mention steepness as a factor. Steepness coupled with distance appears to be a factor in the M6 building especially with feedback from the associated focus group describing the experience as the "continuous downwards spiral". The width of the stair tread width cannot be ignored in terms of visibility for foot placement (Nagata, 2006). Table 7- 9 shows that distance correlates mainly with fatigue for buildings M1 to M4.

Shoe size	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**
Min	**250**	**251**	**243**	**260**	**245**	**235**
Max	328	352	319	352	330	335
Mean	289	294	281	289	290	280

Table 7-13: Shoe sizes for Buildings M1-M6

Figure 7-9: The M2 Stair – "White Out"

There is, however, a dichotomy in the pattern of the results for the grouping of narrow treads, steep stairs and distance for M2 compared with the others as shown in Table 7-4 as the M2 stair has the most acceptable characteristics for steepness and treads width in terms of Figure 7-6 and Table 7-13. The M2 stair is "illegible" in terms of the definition of each step (see Figure 7-9) and overall contrast which may have been estimated by the occupants as being a hazard for foot placement. Distance is the one factor that has a significant relationship to fatigue for M1-M6 ($p<.01$ – reasonably significant) () and this agrees with the grouping in the overall factor analysis in Table 7- 8. Galea et al (2008) clearly illustrates that density can mask fatigue as illustrated in the results for M5.

The falls occurred in M2 and M6. The narrow treads of M6 were mentioned as a problem by the focus groups. The one factor in common is the lack of contrast and poor step definition. The triggers for the falls are multi-facetted (Lord et al, 2006) and yet the common factors are distance and fatigue (Ayis, 2007) which can result in a person not being able to recover from a misstep as easily as others. When fatigue is coupled with other functional limitations, the risk of an incident which could lead to a fall may increase (Jia and Lubetkin, 2005; Horak, 2006; Helbostad et al, 2010; He and Baker, 2004 and Spearpoint and MacLennan, 2012).

There are two outcomes associated with falls which can range from high consequence (fatality or disabling injury) and low probability to low consequence and higher probability (misstep). The likelihood of recovering from a misstep is directly related to fatigue which can also be related to descent speed. The focus group studies in Chapter 6 established a benchmark speed for "free descent" for younger individuals who are reasonably fit[195] which can be compared with the descent speeds for members of the two focus groups who were not fit and had a number of functional limitations. Triangulation between the lower benchmark descent speeds and the actual descent speeds observed in

[195] Assessed using IPAQ in Chapter 6

M1-M6 for individuals with similar intrinsic characteristics are also used to establish falling risk based on focus group comments[196].

7.4.2 Ironing out the Complexity of Estimated Capability (Regression Analysis)

The aim of the PhD Study is:

"*To study the performance of mature age office workers in descending multiple flights of stairs in high rise office building trial evacuations in the context of extrinsic and intrinsic factors".*

The relationship of distance and fatigue can be generalised across M1-M6 but the association between age and obesity/ fitness cannot. There is a reasonably significant relationship for the aggregated data as shown in Table 7-14 which corresponds with larger population studies (Wang and Beydoun, 2007). Three factors have therefore been assembled from the 2008-2010 Case Study data based on factor analysis (Child, 2006), descriptive statistical analysis using pattern matching (Hak and Dul, 2009) and correlation tests being:

- **Stair comfort or descent hazard** representing the grouping of variables shown in Table 7-6 and Table 7-8. The factor analysis is used to reduce the factors into a single all-encompassing variable or factor (Child, 2006)
- **BMI** as representing fitness and associated functional limitations such as balance. Functional limitations were also reduced into a single factor by the factor analysis and represent limitations associated directly with BMI (Booth et al. 2002)
- **Mets** where the non IPAQ measure is a combination of health conditions and BMI and for M5 and M6 is a validated measure of physical activity (Sjostrom et al, 2005) and would also represent the number of health

[196] Fuller Figure and Mature Age Focus Groups commented that the fear of falling increased with the descent speed of the group increasing above a level with which the individual concerned was comfortable.

conditions. Mets also matches with fatigue from the literature (Al-Abdulwahab, 1999).

Estimated descent capability is therefore the dependent variable and the independent variables the above three factors. Bivariate regression analysis is used because of the mix of data types (Blaikie, 2005). The results are presented in the next two subsections.

Variable†	Building	N	R	Significance	Comments
Stair comfort	M1	104	0.15	.005	Rather a weak measure but still significant
Mets(BMI/Health)	M1		.194	.063	No real significance for M1
BMI	M1		.174	.095	No real significance for M1
Stair comfort	M2	142	<1	NS	The stair environment still triggered two falls. – See aggregated analysis M1-M4
Mets(BMI/Health)	M2		<.05	NS	Nor real significance
BMI	M2		<.05	NS	No real significance
Stair comfort	M3	82	<.05	NS	No real significance even with narrow treads
Mets	M3		0.174	.001	Rather a weak measure but still significant
BMI	M3		<.05	NS	Nor real significance even with narrow treads
Stair comfort	M4	99	.212	.05	Rather a weak relationship but still significant
Mets	M4		.113	NS	As per M3
BMI	M4		.170	NS	As per M3
Stair comfort*	M1-M4	326	0.59	.001	Stronger relationship when aggregated
Mets	M1-M4		0.4	.05	Weaker than BMI because health conditions NS
BMI**	M1-M4		0.56	.001	
Stair comfort*	M5	62	.29	.02	Reasonable relationship with METS taken into account
Mets (IPAQ)	M5		.39	.013	IPAQ measure relates significantly with estimated traversal distance
BMI	M5		0.284	.03	Confirms METS (IPAQ)
Stair comfort	M6	170	.221	.006	This building triggered fall due to fear of falling
Mets (IPAQ)***	M6		.177	.03	IPAQ measure still relates but less significantly than M5
BMI	M6		.117	NS	No significant relationship
Stair comfort*	M5-M6	232	.285	.000	Reasonable relationship with METS taken into account
Stair difficulty (overall check)	M5-M6		.285	.05	This building triggered fall due to fear of falling
Mets (IPAQ)***	M5-M6		0.35	.05	Both M5 and M6 show relationship
BMI**	M5-M6		.145	.03	Overall confirms METS (IPAQ)

** Stair Comfort as a variable coincides with the principal component Factor Analyses of both perceptual and measured data dealing with descent risk – those measures such as narrow treads, number of turns and pitch grouped with impact variables such as dizziness and fatigue.*
***BMI showed greatest significance above 35. Mets was a computed variable comprising a mix of BMI and No. of health conditions (Booth et al, 2002)*
****Mets(IPAQ) is the measure based directly on the Short form IPAQ developed by Sjostrom et al (2005)*
† These are interacting variables along the spine of the Ishikawa Chart Model where stair comfort represents a grouping of the stair after-effect variables (Dizziness, fatigue, sore knees, breathlessness etc. and the impact of the stairs that affect descent confidence

Table 7-14: Table of Single "R" regression results with associated levels of significance

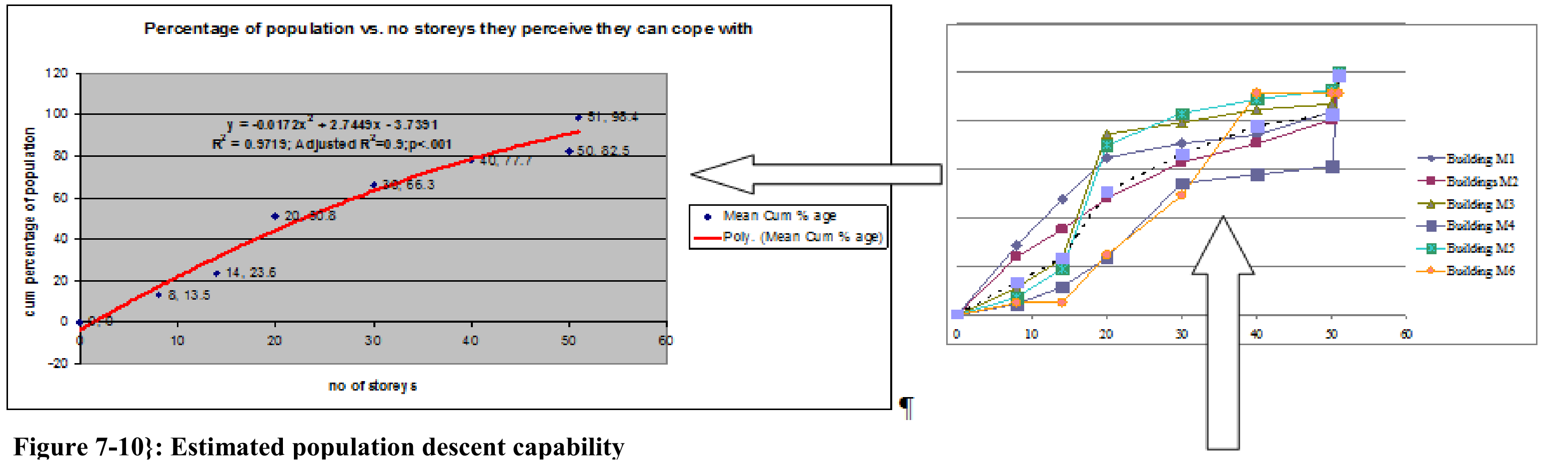

Figure 7-10}: Estimated population descent capability

No. of Storeys	BuildingM1	Building M1	Building M2	BuildingsM2	BuildingsM3	Building M3	Building M4	Building M4	Building M5	Building M5	Building M6	Building M6	Mean
0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
8	28.5	28.5	23.9	23.9	11.1	11.1	4.7	4.7	7.5	7.5	5.2	5.2	13.5
14	19	47.5	11.3	35.2	12.2	23.3	7.1	11.8	11.3	18.8	0	5.2	23.6
20	17.1	64.6	12.7	47.9	51.1	74.4	11.8	23.6	50.9	69.7	19.4	24.6	50.8
30	5.7	70.3	14.8	62.7	4.4	78.8	30.6	54.2	13.2	82.9	24.5	49.1	66.3
40	3.8	74.1	7.7	70.4	5.6	84.4	3.5	57.7	5.7	88.6	41.9	91	77.7
50	9.4	83.5	9.9	80.3	2.2	86.6	3.5	61.2	3.8	92.4	0	91	82.5
51	16.2	99.7	19.7	100	13.3	99.9	38.8	100	7.5	99.9	0	91	98.4

Table 7-15: Data table for estimated descent capability

7.4.3 Estimated Descent Capability M1-M4

Interpreting the results of the bivariate regression analysis from Table 7-14 for buildings M1-M4 where the dependent variable is descent capability:

Stair comfort shows a significant but weak relationship to individual performance for Buildings M1 and M4 so that it cannot be generalised and yet when the sample more closely resembles the general population (aggregated data, N=326) the relationship is highly significant ($p<.001$) with R=0.59.

Mets (BMI/Health) shows a significant relationship for M3 ($p<.001$) with a weak R=.174. This variable cannot be generalised across M1-M4 as there is no pattern. This improves slightly when the data is aggregated as above (N=326) with R=0.4 and moderately significant ($p<.05$).

Body mass index which is not such a good predictor as waist circumference (see BMI Benchmark Focus Group results in Chapter 6) is not significant for any of the buildings M1-M4 and yet when the data is aggregated to more closely resemble the characteristics of the general population it is highly significant at $p<.001$ and R=0.56

7.4.4 Estimated Descent Capability M5-M6

Stair comfort is moderately significant for Buildings M5 ($p<.05$) and M6 ($p<.01$) and therefore could be generalised. This is hardly advisable with single R values of 0.29 and 0.22 for M5 and M6 respectively. When the data is aggregated and more closely resembles a general population profile the relationship is slightly stronger and is reasonably significant ($p<.01$) and R= .285 (N=232).

Validated Mets *(IPAQ)* is moderately significant for M5 (R=0.39 and $p<.05$) and for M6 (R=0.18 and $p<.05$) and therefore could be generalised. This is hardly advisable with the extremely low R values. When the data is aggregated and more closely resembles a general population profile the relationship is slightly stronger (in terms of the R value of 0.35 with the level of significance remaining the same ($p<.05$).

Body mass index is moderately significant for M5 ($R= 0.29$ and $p<.05$) and is not significant for M6. It cannot therefore be generalised. When the data is aggregated and more closely resembles the general population profile a weak and moderately significant relationship is established ($R=0.145$ and $p<.05$).

There is sufficient support for a restatement of the descent capability measure which takes the risk of falling into account as a generalisation across M1-M6 as *y (accumulated percentage population)* $= -0.017x^2+2.7449x - 3.7391$ *(where x is the number of storeys the individual can cope with)* (see Table 7-15 and Figure 7-10). Therefore:

≤ 50% population estimate that they can descend a maximum of 20 storeys without a rest.

7.5 Comparison with Output from Studies in Chapters 5 and 6.

There are two distinct themes in this Section. The first is the longitudinal comparison (1980 through 2010). The second theme is the filtering process. Both themes are shown in Figure 7-11 below

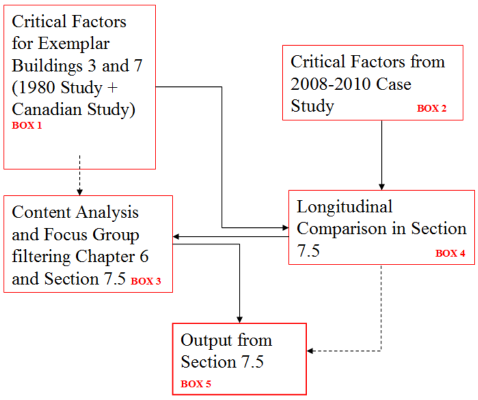

Figure 7-11: Longitudinal and Filtering Analysis Process for Section 7.5

The process step in Box 1 was completed in Chapter 5. Box 2 was completed in Sections 7.2 – 7.4 but the outcome has only been partly filtered by the outcomes from the Content Analysis and Focus Group Studies. The longitudinal comparison (1980 through 2010) is recorded in Table 7-16 to Table 7-19 and comprises the process step described in Box 4. The output from these tables and the associated discussion is then rationalised as represented in Box 3 and summarised in Ishikawa Chart (Box 5) ready for triangulation with the observed and recorded data in Section 7.6.

7.5.1 Longitudinal Comparison (Chapter 5)

The comparison has been limited to those critical contextual factors that are in common with the Exploratory case study in Chapter 5 so that there can be matching between the two data sets. The concerns of Pauls, Fruin and Zupan, 2007) can still be addressed. There is still a need to complete the longitudinal study for the context.

The STAIRS

The results are presented in Figure 7-8 where the factors are reduced to the variable of descent risk/ hazard/ comfort. Narrow treads, slope and estimated distance are the main components. Uniformity and step definition is also included. The construct reliability is assured given:

- 83.9 % of the variance is explained by two principal components.
- The *eigenvalue* for principal component one is 7.8 and 4.0 for the second.
- The cut off values used for the selection of the factors in each component is >0.7.

The above components are therefore for pattern matching between the two data sets where Table 7-16 indicates:

√ ***Steepness*** – The slope of a stair combined with distance to be traversed impacts on the user (see later comments from focus groups). There is no consistent pattern between Buildings 3 and 7 and M1-M6. The former exceed 20 storeys in height so as shown in Figure 7-10 about 50% of the population estimate that they do not have the ability to cope with more than 20 storeys without running some kind of risk of falling. Building 3 is 34 storeys in height and Building 7 is 20 storeys in height. *Estimated ability has decreased to a limited extent over the last 30 years*[197].

√ ***Narrow treads:*** There is a distinct pattern over the last thirty years with foot placement. Based on the work of MacLennan (2011) the mean size of a UK male shoe in the 1980's would have been 300mm. Distance would most likely have an impact here and a lack of step definition could cause people to estimate the treads as being narrow. Buildings 3 and 7 are consistent with M1 and M3-M6 in terms of the pattern. M2 is some 36 storeys so that the distance increases but there are also problems with step definition so that the increase to 45.5% can

[197] Supports Pauls Fruin and Zupan (2007)

be explained. Seeing M6 is some 34 storeys and 31% are concerned the pattern could be said to be consistent across the 30 years. There has been a slight decrease in estimated descent capability as stated in the previous section.

√ ***Handrail easy to locate and use***: The predominant pattern over the thirty years is that any profile appears to have been acceptable. This result can be generalised across all the buildings. It is interesting to note that there is a small constant increase for the buildings of some 7% where circular handrails are used (M2-M6).

√ ***Visibility was inadequate (includes level of illumination):*** Visibility was generally adequate for all buildings except for M1 where the amount of reflectivity off the walls and ceiling were minimal. The level of illumination was inadequate for 15.9% of the population some 10.6% more than the other buildings. When buildings 3 and 7 were visited again in 2011 the level of illumination was well in excess of 100lux. This response agrees with responses concerning step definition. The situation has not changed over the 30 years in terms of occupant acceptance of the visibility provided. The requirement is therefore still a significant factor as indicated in the Canadian Study (Beck, 1977) and also by the Focus Groups.

√ The change over the last 30 years for the STAIRS is that now people are more conscious of the steepness of the stairs associated with fatigue and the fear of falling/ stability. Occupant awareness of handrails and their use is at the same level. Occupant concern about foot placement on narrow treads has more or less remained at the same level over the 30 years with a consistent pattern across all the buildings.

In summary the estimated descent capability for ≤ 50% of the population from the Exploratory Case Study dataset which was assembled in the 1980's was 25 storeys. The same measure in the 2008-2010 Case Study is 20 storeys. This shows a small decrease in stair descent capability. The reason is most likely fitness but could also include other extrinsic contextual factors. At face value it appears that Pauls, Fruin and Zupan (2007) could make a poin*t*.

Variable STAIR	Building ID							
	3 Stair pitch 37^0 33 floor	7 Stair pitch 37^0 20 floor	M1 Stair pitch 34.5^0 10 floor	M2 Stair pitch 30^0 36 floor	M3 Stair pitch 37.5^0 19 floor	M4 Stair pitch 30^0 27 floor	M5 Stair pitch 33^0 18 floor	M6 Stair pitch 37^0 32 floor
Too steep	7.4	5.3	20.8	48.5	23.1	9.3	10.3	28.0
Small treads	32.2	28.1	27.7	45.5	26.1	20.6	18.9	31.0
Handrail easy	66.0	71.2	88.1	95.3	92.4	96.9	98.4	93.0
Visibility inadequate	2.0	5.3	15.9	4.0	1.9	0.0	2.3	3.8

Table 7-16: Longitudinal Comparison: Critical "Stair" factors from survey

Variable GROUP	Building ID							
	3 Stair pitch 37^0 33 floor	7 Stair pitch 37^0 20 floor	M1 Stair pitch 34.5^0 10 floor	M2 Stair pitch 30^0 36 floor	M3 Stair pitch 37.5^0 19 floor	M4 Stair pitch 30^0 27 floor	M5 Stair pitch 33^0 18 floor	M6 Stair pitch 37^0 32 floor
Enter with friend	89.1	82.1	31.4	79.5	48.1	54.7	76.7	67.3
Work location	73.5	53.7	63.6	71.3	74.5	100.0	46.2	75.9

Table 7-17: Longitudinal Comparison: "Group" formation from survey

Variable INDIVIDUAL	Building ID							
	3 Stair pitch 37^0 33 floor	7 Stair pitch 37^0 20 floor	M1 Stair pitch 34.5^0 10 floor	M2 Stair pitch 30^0 36 floor	M3 Stair pitch 37.5^0 19 floor	M4 Stair pitch 30^0 27 floor	M5 Stair pitch 33^0 18 floor	M6 Stair pitch 37^0 32 floor
Sore knees / lower leg	34.0	13.5	9.7	42.4	12.5	9.3	7.9	21.0
Dizzy	16.2	6.2	3.9	39.4	9.6	3.1	6.8	26.0
Dyspnoea	NA	NA	2.9	38.3	9.7	1.0	3.4	11.0
Chest	6.8	2.1	1.9	30.7	3.9	0.0	1.7	4.5
Fatigue	16.2	6.2	5.9	48.1	8.7	8.3	4.8	14.5

Table 7-18: Longitudinal Comparison: “Individual” – impact of stair descent from survey)

Red edging to” fatigue” for M5 low response because of masking effect of density. See also Table 7-19 below confirming increase in density. Triangulates as well in Section 7.6

Variable CONDITION ON STAIRS	Building ID							
	3 Stair pitch 37^0 33 floor	7 Stair pitch 37^0 20 floor	M1 Stair pitch 34.5^0 10 floor	M2 Stair pitch 30^0 36 floor	M3 Stair pitch 37.5^0 19 floor	M4 Stair pitch 30^0 27 floor	M5 Stair pitch 33^0 18 floor	M6 Stair pitch 37^0 32 floor
Alone	14.0	11.6	26.9	6.5	10.5	30.2	0	2.0
Few others around	48.0	51.6	69.2	50.0	71.4	67.7	5.0	15.0
Crowded but moving	22.7	20.0	2.9	39.8	15.2	2.1	21.0	76.0
Very crowded and slow	15.3	16.9	1.0	3.7	2.9	0	74.0	7.0

Table 7-19: Longitudinal Comparison: “Group” and “Management” impact of density

The Group (You and Others)

The results are presented in Table 7-17 to Table 7-19 above. Group formation appears to follow a loose pattern internationally and over the last 30 years a generalised finding (Yin 2009) can be made from the range of percentages in Table 7-18 that more than 30% of occupants will form groups in trial evacuations. The rate of formation can also be affected by the action of wardens (Management) as shown in Table 7-14 ($r>0.3$ and $p<.01$) for M3 and M5-M6. An indication of internal cohesion over the 30 years shows up in the responses as to where the groups were formed. The responses range from 46% to 100.0% so that a generalisation can be made that more than 40% of the groups will have been formed at the work station location on the floor. Seeing altruistic behaviour[198] would be expected as explained in the Content Analysis studies in Chapter 6 the risk associated with helping others who may have fallen or where members who have to increase their pace to keep up would not have changed. Also refer to the Fuller Figure and Mature Office Worker Focus Group studies in Chapter 6.

Density, Delays and Merging

The results are presented in Table 7-17 to Table 7-19[199]. Spearpoint and MacLennan (2012) make the point of the impact of fatigue in stair descent which is further borne out by Peacock et al (2009) who show a reasonably significant ($p<.01$) relationship between distance traversed and the slowing of descent speed. This is not the finding of Galea et al (2008) from their findings on the WTC 9/11 incident where they conclude that density may mask this issue. Delays can also

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[198] Also as described in Canter et al, Human Behaviour in Fires, Edition 2.

[199] Table 7-18 is included because of the discussion of the masking effect of density on fatigue in M5.

be caused by various merging patterns (Boyce et al, 2011). The pattern of "crowdedness" in all the buildings over the 30 years indicate that no more than 20% of the occupants see themselves as being held up due to others in the stair. This is yet to be triangulated with the measured density and descent velocity in the stairs in Section 7.6. The only building where density had an impact was in Building M5 where 74% of the respondents stated that the stairs were "very crowded and moving slowly". This is readily evident from the M5 stairs descent chart (Appendix A7.6). Table 7-18 shows the lowest response for the number of occupants suffering from fatigue as being M5. This is considered to be the impact of density. Management can therefore impact on descent simply by the evacuation strategy and sequence they adopt.

The Individual – impact of descent and the Group.

The results are summarised in Table 7-18 as:

- **Lower limb pain**: The pattern shows up readily over the 30 years where an increase in distance or storey height is linked directly with increased lower limb pain (Building 3 is > 30 storeys as is M2 and M6). Buildings 7, M3, and M4 averaged 20 storeys and had similar response rates. M5 did not match the pattern because of masking by density and delays. The response rate for M2 was noticeably higher (42.4%). The building is some 36 storeys high and the internal temperature within the stairs exceeded 40^0C. The mean response rates were similar over the 30 years so that as a functional limitation its level did not really change.

- **Dizziness/ Vertigo**: This shows a similar pattern as before with a visible influence of height and distance which bears out the findings of Templer (1992) and Archea et al (1979) and the nature of these conditions linked with health science (Bredenkamp, 2009; Samy and Hamid, 2010; and Yardley, 1994). Agoraphobia (NCBI, 2012) which is a fear of heights associated with being locked in a space is also linked with vertigo/ dizziness. The pattern is therefore consistent across the 30 years as per the previous bullet point.

- **Chest discomfort and breathlessness:** The pattern is consistent as before except for M2 (30.7%) where the temperature was excessive and there was no ventilation.

These conditions were all grouped together in the factor analysis with a cut off value >0.7. Other results still include the impact of reduced vision and impaired hearing on orientation so that these should still be included amongst the most important functional limitations. These results will now be filtered by the outcomes of the focus group and content analysis studies in the next section.

7.5.2 Further analysis of core consistencies or classifications using results from Chapter 6

Comparative tables are used to analyse each of the core consistencies outcomes from Chapter 6 with that of the previous section. Once each core consistency has been filtered establishing the context of occupant descent performance then the latter will be analysed (regressions and efficacy of reporting instruments) and discussed prior to triangulation in Section 7.6. **Each of the core consistencies comprising the Context are compared in** Table 7-20 **to** Table 7-23 **and the conclusion is listed in the Column labelled "Filtered Outcome":**

Category or Factor	Focus Group/ Content Analysis Study	Comments from 7.5.2	Filtered outcome
Age	**Age does have an impact on fitness. Mature age – increase in functional limitations. Descent speed measurements confirm this – Table 6-23 and 6-30.**	**Not shown to be significant**	**Retain as evidence comes from general population studies as demonstrated in Chapter 2 and focus group outcomes**
BMI/Waist Circumference	**The measured descent speeds (0.33-0.36m/sec) matched those of other studies. Some comments related to balance.**	**Correlation does not really show significant results between obesity, estimated distance and balance on building by building basis. When linked with health conditions this improves and also when M1-M4 and M5-M6 are aggregated.**	**Balance and relationship to fitness should be maintained (Booth, 2002).**
Functional Limitations			
Generally	**Important functional limitations cited were reduced vision (depth perception), arthritis, asthma (see also BMI Benchmark Group, weak ankles, reduced strength, poor orientation ability, disturbed gait, vertigo and dizziness, fear of falling. Also important was fear of others falling and masking the definition of the steps.**	**Correlations and factor analysis confirm arthritis and lower limb pain, fatigue with distance, number of health conditions impacting upon fear of falling (100% correlation at p<.01 across M1-M6, balance, chest discomfort and breathlessness.**	**Combine focus group and survey results especially with confirmation of impact of functional limitations by descent speed. Concern about personal safety was still significant for Buildings 3 and 7 and this is confirmed in the continued safety concerns with small treads and steep stairs.**
Fatigue	**Content Analysis comments such as 102.24 and 102.65 show impact of fatigue. Focus groups mentioned fatigue as being exacerbated with the "downward spiral" effect.**	**Fatigue was not tested directly via regression but it did correlate highly with distance (too many flights) and the number of health conditions. This was confirmed by the grouping of the impact of descent together with descent risk showing that the associated data could be reduced into those variables. Fatigue was allowed for in the measures of fitness that were used for M1-M4 and then the IPAQ measure for M5-M6.**	**The impact of the downward spiral was also observed on the stairs with 4 turns per storey in M6 where the number of people within a group increased from 3 out of 10 to all ten. The findings therefore will be combined.** **High regression returns for the Exploratory case Study were not confirmed by the 2008-2010 Case Study**
Fitness	**Mentioned as being related to obesity and slow movers. Not really mentioned so the measure was recoded. Focus groups recognised the importance and related it being embarrassed in group situations when they had to travel at a faster speed making the individual feel uneasy.**	**Regression measures did not confirm the finding of fatigue related measures derived from the exploratory and focus group studies.**	**Focus Groups did not really contribute any additional factors but triangulation will confirm the impact of increased speed on the risk of falling.**
TRIANGULATE WITH OBSERVED AND MEASURED DATA			↔

Table 7-20: Individual Core Consistency Filtering Schedule

Category or Factor – (GROUP)	Focus Group/ Content Analysis Study	Comments from 7.5.2	Filtered outcome
Group formation	**Not addressed by Focus Groups. Content Analysis Studies confirmed groups were formed on the floor, for a purpose to assist and linked to management procedures.**	**Confirmed longitudinally that >30% of population formed groups before entering the stairs (generalised) and that the majority were formed on the floors.**	**Groups were formed by Management and voluntarily. Could be altered on the stairs in minor instances where someone needed special assistance and other members of the group were unable to help.**
Group dynamics	**The impact of the slow mover was mentioned by the Focus Groups and also obstructing other's view of the steps. Also mentioned fear of others falling. Extensive criticism of the slow mover in Content Analysis (NY Times Blog)**	**Impact of the slow mover was highlighted in part and is also shown on the stair descent charts.**	**Retain findings from Focus Groups and Content Analysis Column.**
Group behaviour	**Group delays occurred mainly because of merging. Altruistic behaviour confirmed from 102 Minutes Content Analysis independent of where the group was formed. Focus Groups did indicated annoyance at amount of group "noise" and also unfocussed behaviour. Focus Groups also mentioned the problem of moving at an uncomfortable speed because they were too embarrassed to ask the other members to slow down. They mention the increased risk of falling**	**2008-2010 Case Study did indicate indirectly the impact of delays but occupants were generally unconcerned as compared with Content Analysis findings.**	**Altruistic behaviour will be emphasised especially in terms of cohesion (see stair descent chart path traces for low amount of overtaking). The risk of falling should be retained where connected with group descent speed. Enhanced by focus group descent speed analysis and comparison between the functional limitation Focus Groups with the BMI Benchmark Focus Group. This finding will also be used in the Triangulation Process.**
Group Knowledge	**Main feature of 102 Minutes Content Analysis Study and special Focus Groups where groups knew exactly what to do.**	**Mentioned in 2008-2010 study via amount of prior evacuation experience using the designated stair and forms a set pattern across M1-M6.**	**M2 is lowest as UAE requirement is not clearly law Generally >33.3% (generalised). Focus group comments should be added.**

Table 7-21 : Filtering Schedule for the Group Core Consistency.

Category or Factor (STAIR)	Focus Group/ Content Analysis Study	Comments from 7.5.2	Filtered outcome
Narrow treads	**Not mentioned in Content Analysis but extensively referred to in Focus Group especially in relation to size of feet and maintaining a front on stance.**	**There is a significant percentage of the population over the 30 years (>18%) across all buildings and >25% where treads were less than 260mm.**	**The outcomes complement one another and increase with distance.**
Steepness	**Comfortable pitch considered as 37⁰ but outcomes were modified in relation to increased distance and number of turns – "downwards spiral".**	**Extremely high correlation with fatigue for all M1-M6 and estimated distance.**	**Survey results given more credence because of pattern of correlation across all buildings and also maintenance of similar pattern in the Exploratory Case Study.**
Handrail access	**Focus group confirmed findings of Reeves et al (2008a) about increase in confidence with easily accessible handrails. They need to be conspicuous and reachable. Should have one on each side of the flight.**	**2008 – 2010 Case study show general pattern of satisfaction. Triangulation will show that rate of handrail use increases with the distance descended.**	**Importance of handrails confirmed by focus group in terms of having additional one available. This applies especially where stairs need to wider for resting as pointed out by Focus Groups. See Author Case Study in Appendix A7 where even with 1200mm clear width some morbidly obese individuals will lower limb pain will need two handrails to prevent them from falling and negate the benefit of increased stair width.**
Visibility	**Focus Group mentioned the problem of lack of contrast between surfaces and step definition. See Management re illumination**	**Generally respondents were satisfied with visibility mainly due to adequacy of the illumination. M8 focus group raised issue of lack of contrast and lack of contrast was one of reasons for fall in M2.**	**Contrast retained as a critical factor even taking 2008-2010 results into account. See also Alderson (2010). Concern also raised in the Exploratory Case Study (Beck 1977).**
Spatial	**Content Analysis Studies both highlighted the need for wider stairs confirming Peacock et al (2009) to allow for non invasive overtaking. Also made point that this would provide space for resting.**	**Not shown directly in 2008-2010 Case Study but implied.**	**Retain Focus Group and Content Analysis findings – also supported by observations in M6 evacuation where individuals did rest. Density was low here so that resting was possible due to altruistic behaviour and that is permitted in practice.**
Uniformity	**Not mentioned**	**Not mentioned**	**Retained as critical due to observations.**
Others			**See Management**

Table 7-22: Filtering Schedule for STAIRS.

Category or Factor Management & Maintenance	Focus Group/ Content Analysis Study	Comments from 7.5.2	Filtered outcome
Warden communication and direction	**Finding in Table 6.39 was that this issue should be localised and simple to avoid confusion and that it should be practised. Management should be committed to it and occupants encouraged to participate. Focus Groups were annoyed by group members who did not take trial evacuations seriously and also did not know what to do. 102 Minutes Study showed the value of the above.**	**2008-2010 Study showed frequency of practice being > 33.33% and in most situations being more successful. Descriptive statistics analysis shows longitudinal benefit in Building 3, M3, M4, M1 and M5.**	**Focus Group comments are crucial and this is further exemplified in the report on the evacuation of the Cook County Office Building by Proulx and Reid (2006). Comments were used to enhance descriptive statistics results for M1-M6.**
Evacuation Strategy	**Mention of responding when the floor is ready as per Building 3, M1, M3, M4, and M5 which is connected with an uncontrolled evacuation strategy (Pauls, 1977). 102 Minutes shows success of this localised approach for some major tenants. This is what they practised.**	**Mention of responding when the floor is ready as per Building 3, M1, M3, M4, and M5. Strategy not really discussed by Focus Groups, Practise was mentioned, however,**	**Filtered as having a simple strategy and practising it.**
Group formation	**Groups were already known in the 102 Minutes Study for larger tenants. This included the buddy technique and the training of group members to assist those who required it as per the evacuation chair example.**	**Group formation is generally high across M1-M6 and influence of management varied.**	**Focus Group outcomes should be coupled with evacuation strategy being simple and understandable. Focus Groups were intolerant of actions of those occupants who did not know what they had to do.**
Maintenance	**Mentioned by Focus Groups in relation to adequacy of illumination, ventilation and cleanliness.**	**Significant relationships were found in the Exploratory Case Study especially the Canadian Study (Beck 1977). Not really highlighted in the 2008-2010 Study.**	**Finding as Management critical factor to link Exploratory Case Study outcomes with current opinion from Focus Groups.**

Table 7-23: Filtering Schedule for Management Core Consistency.

Conclusion

The conclusion that can be drawn from the comparison between the Exploratory and 2008-2010 Case Studies for each of the contextual core consistencies is shown in the yellow highlighted column in Table 7-21 to Table 7-23. These findings are to be triangulated with the measured and observed data in Section 7.6.

7.5.3 Author based Case Studies

The two studies are described in detail in Appendix A7.4 with the results. The studies comprise:

(a) An assisted evacuation study of stair descent device similar to that tested by Adams and Galea (2011) and Zmud (2007) as the original devices had only catered for persons who were not morbidly obese.

(b) Individual descending stairs without assistance for six levels during the Christchurch Earthquake where no provision had been made in the evacuation procedures.

These two case studies supplement the PDSA Cycle 3 process to provide additional clarification for the problem of simplified assisted evacuation methods for heavy mobility impaired persons and removing the risk to the group for the case study in (a) and addressing the dichotomy of wider stairs and the problem of reaching both handrails for the case study in (b).

Assisted Evacuation Case Study Results

Adams and Galea (2010) utilised a 75kg subject for the Evac-chair test. The likely BMI would have been 22. The author being the person immersed in the PhD case study (Yin 2009) is still classified as Class III obese having a BMI of

33. During the 1980's he had a BMI of 56. In order to view the descent speed results from the Adams and Galea (2010) study in context and in relation to the WTC9/11 Content Analysis of Dwyer and Flynn in Chapter 6 the author conducted a test with the permission of the suppliers of Evac-chair® using the model 1-440 as the descent vehicle. This model is designed to carry people with a mass limit of 200Kg or 440 lbs.

A total of six test runs were conducted for the reason of internal validity so that the comparison with the Adams and Galea (2010) study could be placed in context. The procedure and results are discussed in Table 7-24 below.

Characteristics of Respondent					Time and Speed(Comparison with Adams and Galea, 2011)		
Run No.	Mass	BMI	Walking	Evac+Chair®	Time	Speed	A/G Adjusted speed
1	75	22			4.96	0.83	NA
2	130	33			10.22	0.41	NA
3	75	22			8.5	0.49	0.78
4	130	33			11.9	0.35	0.56
5	130	33			12.5	0.33	0.53
6	130	33			12.9	0.32	0.51

Table 7-24: Test Results and Comparisons

The highlighted column shows the measured speeds adjusted to match Adams and Galea (2010) taking into account speed gained by multiple descents which is similar to speeding up of descent recorded by Peacock et al (2009) for most likely the same factor.

Table 7-24 shows the respondent characteristics and test type together with the resultant descent time for the flight together with the mean descent speed. The measurement commenced at 'toe-off' the first riser for walking and commencement of movement of the Evac+chair® with the key point being the leading knee of the respondent to ‘heel-down’ on the next lower landing. The travel distance was calculated at 4.122m.

Device	Average travel Time (seconds)	Number of Handlers in Emergency	Average Speed in metres/ second.
1. Evac+ Chair (75kg)	209	1	0.81
2. Carry chair (75kg)	297	3 male or 4 female	0.57
3. Stretcher (75kg)	305	4	0.55
4. Drag mattress (75kg)	272	2	0.62
Drag mattress (180kg)	210	5	0.13

Table 7-25: Adams and Galea Study (2010)

The travel speeds from the spot test were then adjusted by the ratio of the travel speeds recorded in the study (Adams and Galea, 2010) to that recorded in the test. The ratio was 1.61. This was repeated for tests 4-6 so that the speeds could be compared with the other handling methods in Table 7-25. It is interesting to note that the 1-440 chair matches that of the stretcher. The highlighted row in Table 7-25 which represents a mattress drag conducted with the author as a respondent in a New Zealand test evacuation of a large hospital through 4 storeys only resulted in descent speed of 0.13m/sec which is well below the speeds actually measured in the Author’s comparative test. A model 1-440 chair would still be within the range of descent speeds recorded in many trial evacuation studies for ordinary stair walking (Fahy and Proulx, 2001).

The test stair had a slope of some 38^0 and the individual had a BMI of 36 with a mass of 130Kg. 38^0 is considered as a steep stair when compared with Table D2-13 of the Building Code of Australia (1996-2011). This pitch was to act as a worse scenario for the transport of the morbidly obese individual down a flight comprising some 13 risers with the test being completed a number of times to simulate multiple flights of stairs. The evacuation device is known as the Evac-chair® Model 1-440 designed to cater for a 200Kg maximum load.

The results were "adjusted" as shown in Appendix A7-4. A speed of 0.8m/sec was achieved but decreased to 0.5m/sec over further trials. The latter is still nearly comparable with the slowest descent speed, for the BMI Benchmark Focus Group, of 0.6m/sec. The mean speed over all the tests did not correspond to that for the 75Kg chair in Adams and Galea Study of 0.81m/s but the results from the first run did. This means that 0.8m/sec is achievable.

The net impact of this example of group assistance using trained members further confirms the findings from the 102 Minutes Case Study and the description by Zmud (2007) and confirms a way forward for evacuation planning without having to resort to evacuation lifts.

Christchurch Earthquake Evacuation Case Study

The actual event is described in Chapter 4 and the Appendix A4. The author took some 80 seconds to exit the building with a descent speed of 0.6m/sec which is the same as the slowest descent speed of the BMI Benchmark Focus Group members. The author's BMI was 36 and his waist circumference 1250mm. He has pain in his lower limbs (knees) as a result of motorcycle injuries. During descent he relied heavily for support on the two handrails.

A group comprising colleagues from the local work area followed the author into the stairs. The author's body ellipse area was $0.35m^2$ with the mean of the rest of the group being approximately $0.23m^2$. A body ellipse of $0.35m^2$ occupied most of the available width of the stairs so that overtaking would have required the person behind to dislodge the author's arm. This was a doubtful behaviour given the altruistic attitude of the group.

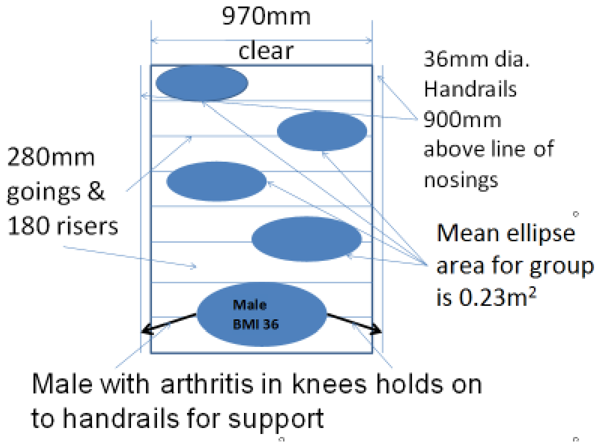


Figure 7-12 – Diagrammatic plan view of descending group

Figure 7-12 shows the distribution of the group. The clear width of the stair was some 970mm. Peacock et al (2009) show that wider stairs are one of the critical factors to facilitate counterflow and allow for overtaking.

MacLennan and Ormerod (2011) point out that widening exit stairs do not solve all the problems. A stair with a clear width of 1200mm with two handrails as suggested by some (Pauls et al, 2007) may provide space for resting on larger landings but should this scenario occur then a morbidly obese individual could cause a serious delay.

The provision of the second handrail is also vital as shown in the study so that a single handrail is considered to be inadequate. Morbidly obese individuals have problems with stability (Teasdale et al, 2007 and Corbeil et al, 2001).

The overall outcome of the case study described in Appendix A7 is presented in Figure 7-13 below.

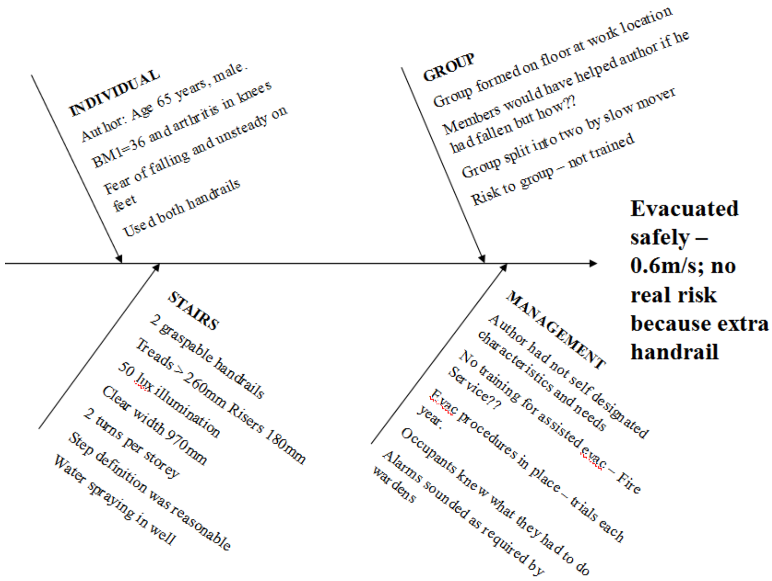


Figure 7-13: Ishikawa Chart Summary of Author's Earthquake Evacuation Case Study

This case study filters the discussion on the widening of stairs showing how an individual can still obstruct counterflow and overtaking. The 102 Minutes Content Analysis Study provides a similar scenario where the space was taken up by two people i.e. one male assisting a morbidly obese female. Management can still cater for this through the development of a personal emergency evacuation plan for the individual with functional limitations so that this delay is avoided or catered for. The benefits of the wider stair are vital for morbidly obese people as well as this measure provides for optional and flexible resting spaces within the stairwell. Management can still facilitate overtaking as well.

7.6 Triangulation

7.6.1 Introduction

The triangulation process is described in Chapter 3 and referred to in Section 7.1. Only the critical factors will be triangulated from the framework provided in Table 7-21 to Table 7-23. The details are also available in Appendix A7.

The triangulation results are presented in a hierarchy comprising:

- Measured data and observations
- Video data analysed and presented as stair descent charts, density, velocity and regressions schedules
- Triangulation tables.

Schedules of the measured data are presented in Chapter 4 and Appendix A4. The data was reduced via factor analysis as per Table 7-25 and triangulated with the estimated data presented in Table 7-26.

Video data is reduced to stair descent charts, spread sheets and schedules from which the basis of the data for triangulation with estimated "visual" data and occupant survey responses. The overall data set is available in Appendix A7.6.

Triangulation schedules are presented in this section as the main purpose is to present the results of the "triangulation analysis" backed up with observations and comments for each of the core consistencies.

7.6.2 Triangulation from measured data analysis

The two exemplar buildings from the Exploratory Case Study are included to complete the triangulation process. Principal Component Factor Analysis (SPSS V16) was used to reduce the number of measured variables to facilitate comparison with survey variables.

Variable	1 (8)*	2 (7)*	3 (4.8)*	4 (3)*	5 (2.8)*	6 (2.1)*
Tread width			0.7			
Riser perceptive	0.9					
Stair pitch	0.8					
Uniformity		0.7				
Handrail ffp	.77					
Handrail dia						.8
Illumination				.93		
Step legibility					.89	
Nosing sharp		0.9				
Confidence	.76					
Wide well	.71					
Orientation			.84			
Maintenance			.83			
Space for rest				.76		
Distance				.83		
Tread width/ shoe ratio			.74			
Riser height	.94					
Width						.92
Falling height		0.93				
COMPONENT DESCRIPTION	DESCENT RISK	FALLING HAZARD	STEPPING CONFIDENCE	CLEAR PATH AND SPACE TO REST	STEP VISIBILITY	SPACE TO SAFELY MOVE

*Factor analysis of data from observer template – selection value ? 0.7. *Eigenvalues slected as >2.*

Table A7.6-1: FACTOR ANALYSIS Buildings 3,7 and M1-M6: Observed and Measured Factors/ Variables.

1-3 = descent risk

Table 7-26: Factor Analysis – Observed and Measured Data

Variable	Component	
	1(7.8)*	2(4)*
handrail easy to find		.948
first step easy to find		.970
each step easy to find		.972
Last step easy to find		.970
stair gradient	.839	
treads too small	.826	
too many flights of strs	.881	

Reinforced via focus group comment about continuous downward spiral, narrow treads in relation to size of feet, width of well (rich views) and relation to fear of falling to health impacts such as dizziness/ vertigo and safe feelings.

Table 7-27: Factor Analysis Survey

Table 7-26 shows the output from the Factor Analysis of the Observed and Measured data. The eigenvalues for each component vary from 8.0 to 2.1

and caters for approximately 80% of the variance. The cut off values for the individual factors "adhering" to each component exceeds 0.7 which demonstrates the strength of their relationship. The nominated "cut-off values" are in line with those recommended in the literature (Child, 2006 and Kline, 2008). Table 7-27 shows the survey result. The variables from the survey reduce readily to two components whilst the measured ones reduce to six components. The first components from each triangulate easily as they are concerned with descent risk. It is reasonable to extend this meaning to include falling risk and stepping confidence so that components 1-3 in Table 7-26 (red dotted frame) can be grouped together. This triangulates well with the estimated STAIR attributes in Table 7-27 and is enhanced by the focus group comments concerned with the "downward spiral" (directly related to distance) and the agoraphobic issues described in the Content Analysis of the 1977 Canadian Study (Beck 1977). The remaining three components in Table 7-26 can be similarly grouped under Visibility and Support.

Stair geometry and width

Treads measured 260mm and 259mm in Buildings 3 and 7 and were rated as poor. 30% of the occupants agreed with this. Considering the average male shoe size would have been approximately 300mm as shown elsewhere (MacLennan 2011) the triangulation agrees. The slope of the stairs was 36^0-37^0 which attracts a similar rating as the treads but only 7% of the occupants were concerned.

The treads in M1 were 280mm with a mean shoe length of 289mm. The pitch of 32^0 is within the preferred zone in yet 27.7% of the respondents thought they were too steep. This is attributed to the length of the stair flights between levels ("roller coaster effect"). The treads in M2 were 300mm and the mean shoe length 294mm. 45% of the occupants thought the stairs were still too steep. This is attributed to the lack of step definition and the increased descent distance. The treads in M3 were only 245mm wide with an associated falling risk 12 times that of the other buildings. The mean foot length was 290mm with a maximum of 330mm. Only 26% of the occupants were concerned. The pitch of the stairs was 38^0 which is unacceptable according to Figure 7- 5. Only 26% of the occupants were concerned. The treads in M4 are 260mm wide and the pitch is a comfortable 30^0. The mean shoe length is 289mm with a maximum of 319mm. 21% of the occupants were concerned. The distance is greater than M1 and M3 so that this would account for the slight increase in concern. The treads in M5 measured 270mm and the pitch was 32^0. The mean foot length was 290mm with a maximum of 330mm. This reflects the relationship for M4 so there is a pattern with distance. M6 treads were 260mm with a pitch of 37^0. The mean foot length was 280mm with a maximum of 335mm. The percentage of concerned occupants increased being exacerbated by the increase in descent distance (also confirmed by focus groups).

Uniformity was an issue in Buildings 3, 7, but only concerned 8.5% of the occupants. Uniformity was reasonable in M2 – M6 and this was reflected in the comments.

Handrails – provision for support

In every case respondents easily found the handrails. This did not match the measured number, contrast and graspability. Observations show that 25% of each group started off holding the handrail and that this increased on average to 40% at the lower levels. The focus group comments reflected the comments of Reeves et al (2008a) re the increase in user confidence associated with handrail use. The author's case study shows the opposite end of the spectrum where someone relies heavily on handrails and relies heavily on graspability and a handrail on each side of flight to mitigate any perturbations. This reflects the findings of Maki et al (1998).

Stairway visibility

87% of the occupants in Building 3 and 80% in Building 7 had no problem with visibility which reflects a lighting level of >50 lux. Building 7 had severe shadows affecting stair legibility at various points but this did not show up. The illumination levels in M1-M6 were all reasonable. In M1 and M2 the stair legibility was poor. There were a significant percentage of occupants who were concerned in each case. In M1 the percentage peaked at 25%. M2 only peaked at 10.4% and yet the stairs were virtually illegible (white). This building is where the lack of step definition was one of the triggers for one of the falls. Concern for step definition was also expressed by the focus groups especially in terms of those with reduced vision with poor depth perception.

M3 and M4 had a reasonable overall level of contrast between vertical and horizontal surfaces with marked nosings. Less than 3% of the occupants were concerned. M3 and M4 triangulate reasonably well although the occupants were familiar with the steps because of their past evacuation experience.

M5 with good step definition and illumination triangulates well and this is reflected in a low rate of concern of some 3%. M6 had grey walls and grey treads but the nosing were marked in yellow. These were “white-out” conditions for some as indicated by the focus groups and yet only 6% of the population were concerned. The pattern of triangulation was quite weak and yet M2 did not match at all. It is no coincidence when visibility is exacerbated by distance and the constant “downward spiral” that it would be the sites of one of the falls.

Overall comfort, ventilation, orientation, falling factors, familiarity, management and resting space

Buildings 3 and 7 did not triangulate re maintenance where 3 was well maintained and 7 not. This changed for management where Building 3 had a much higher level of practice and participation. Falling height or downward spiral triangulated well for the steep stairs in each case (25%-30% concerned).

Overall comfort is redefined as descent risk from the reduction of factors carried out in the factor analysis. “Too many flights” that reflects the focus group comment, “downward spiral” is central to this especially with an increase in distance traversed. The degree of correlation between the number of health conditions (stated separately in the correlation matrix in this chapter) across the entire group of buildings ($R>0.3$ and $p<.05$) along with fatigue confirms this measure.

In terms of triangulation the marked break in the overall pattern of responses is for M2 where distance, lack of ventilation and whiteout conditions exacerbate the locating of each step by the occupant may cause them to estimate that the treads are too narrow and stairs are too steep. The treads are 300mm and the pitch is only 30^0. Otherwise the level of comfort or descent risk concerned some 20% -30% generalised across M1, M3, M4 and M6 where the stair geometry was of concern (Johnson and Pauls, 2011 and Roys, 2006). M5 did not triangulate because of the slow descent speed which has already been discussed.

Management is measured by evacuation experience, use of a designated stair and also degree of crowding as relating to the reduction in descent speed. There was a consistent pattern across all M1-M6 of > 70% except for M2 which was 33.3%. This triangulates completely for all buildings especially given the malfunctioning of the fire alarm and the stair ventilation systems in M2. Also many of the levels refused to participate in the trial evacuation. This is also the building that the two falls occurred in. The fastest evacuation times reflected the adoption of a “one out-all out” or uncontrolled evacuation policy where the procedures were simple. This was also reflected in the experience level of the occupants (M1, M3, M4 and M5). The M6 strategy was sequential but had been regularly practiced as reflected in the experience rate of 85%. It was still more complex.

Familiarity with the stairs is rated as 4 for M1, 2 for M2, 4 for M3, 2 for M4, 2 for M5 and 5 for M6. The response from the occupants shows evacuation experience >70% and their use of the one designated stair for those evacuations.

The response for the designated stair exceeds 80% in most cases. The difference to this is M2 where the experience is 33% and the use of a designated stair at 50%. The triangulation here is pattern matched (Hak and Dul, 2009)

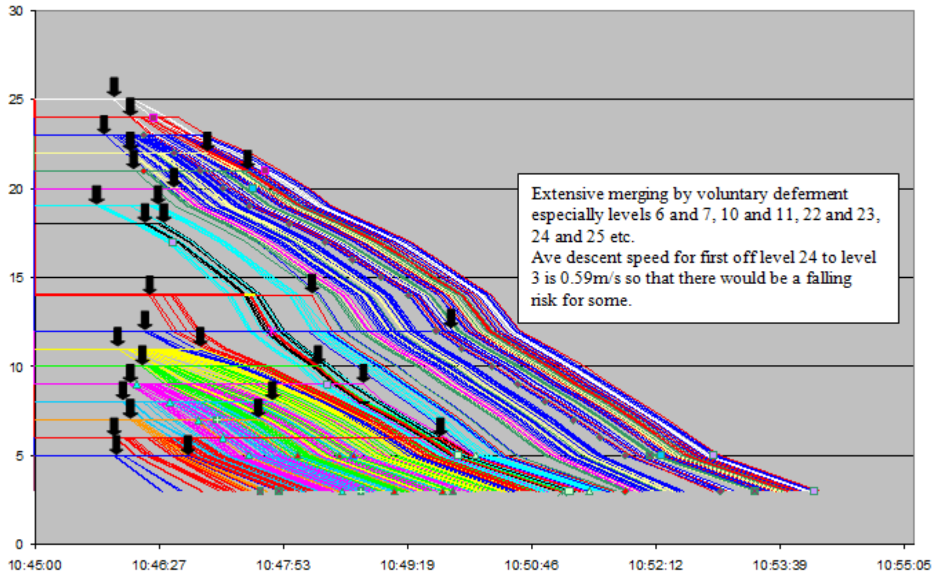
Resting space cannot be triangulated but applies given that response rates for “too many flights” correlates well with “fatigue” in the matrix in this chapter. Video observations marked with the relevant symbol for M6 in the next section show people resting. This was observed in other buildings but could not be verified between the observer comments and video based data. Resting spaces were available in M1, M2, M3 (Stair 1), and Stair 2 in M6.

Falling height is the height between landings. This was not considered to be critical by occupants in their response concerning fear of falling (<6%) except for M4 where it increased to 14%. The falls produce an interesting dichotomy. Reducing the falling height by increasing the number of turns where the number of storeys exceeds 20 may be a problem given the pattern associated with distance reflected in M2 and M6 where the percentage of occupants reported fatigue, dizziness and vertigo as the impact of descent increased to an average of 43% and 25% respectively a good 100% increase over the other buildings. The above can be generalised across M1-M6 and is also consistent with comments from the focus groups. Provision of resting spots is therefore more suitable so that occupants can rest and reduce the risk of falling as they will not be so tired (Helbostad et al (2010).

7.6.3 Core Consistency Observations and Comments from Video Data Set.

Figure 7-14 shows the Stair Descent Chart and Schedule for Building M1 and this is typical for all the buildings, one chart for each stair. All the stair descent charts are located in the Appendix A7.6. The x-axis represents the elapsed time from the first occupant entering the relevant stairway to the time the last occupant passes the final exit point or a pre-determined point on the ground floor. The y-axis represents the storeys in consecutive order above the ground floor. Each coloured line therefore represents the rate of progress down the stairs. They are colour coded to represent the floor of origin. Red lines in all cases represent observers descending with the occupants which are used to triangulate the observations of the images captured by the video cameras. Figure 7-15 shows examples of symbols inserted on the charts which are explained on the schedules attached to each chart. These comments provide a description of such events as occupants overtaking and resting including a description of occupants' intrinsic characteristics. These charts and associated audio files also provide further information on descent speeds and triangulation of group formation and have been used to derive the triangulated information shown in Table 7-28 and Table 7-29.

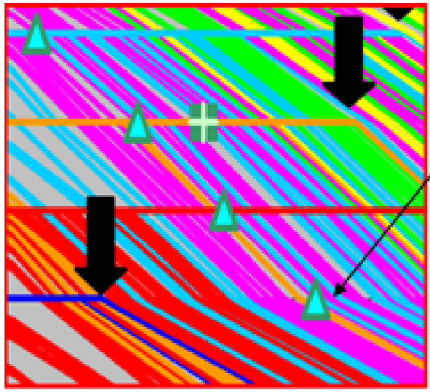
Tables 7-28 and 7-29 are summaries of the triangulation tables located in Appendix A7. Table 7-28 is concerned with whether or not fatigue and hence the risk of falling (Lord et al, 2007) is associated with lack of fitness as indicated by BMI and/or functional limitations. The triangulation is matched with R squared as a measure of density on the stairs related to the descent speed. Table 7-29 is a triangulation between density as indicated by survey respondents and that actually measured from the vide3o data. These tables and the associated outcomes are discussed further in this section.



◆	Green edging – from level 21 slim female less than 35 years no handrail but holding up others behind her.	
◆	Green edging – from level 23 slim female less than 35 years using handrail holding up others behind her.	**NOTE:** 50% of those observed were female and of those 80% using the handrail. Descent speed is approx 0.59m/s.
■	Green edging – from level 21 overweight male using handrail and holding others up.	
■	Pink edging – from level 24 slim male 35-59 years of age using the handrail and overtaken by others – slow mover with apparent functional limitations.	
■	Green edging – from level 19 slim male 35-59 years of age not on handrail and holding others up behind him.	
Yellow bar	Observer starting as yellow bar at level 14 with 4 in front and 1 on handrail to 10 in front and 4 on handrail at level 10.	
Purple cross	Slim females from levels 5 and 9 over 60 years using handrail and holding others up behind.	
Yellow cross	Overweight male from level 9 using handrail and significantly overtaken.	
▲	Blue edged - slim female from level 9 – 35-39 years of age with high heels and using handrail.	
▲	Green edged – slim female from level 9 35-39 years using handrail and holding others up behind.	
□	Green edged – overweight male 35 – 39 years using handrail and holding others up behind	

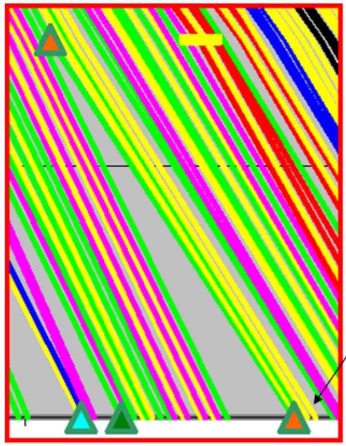
Figure 7-14: Specimen Descent Chart for Building M1 and Observation Legend/ Schedule forming data base in Appendix A7.6

Figure 7-15: Example of use of coloured infill and edged symbols to locate occupants and observers on the M1 stair descent chart.



This occupant from Building M4, Stair 1, marked by triangles in this picture, shows signs of preferring a slower descent speed, but kept up with the speed of others.

She was middle-aged, obese, wore sports shoes, and held the handrail.



This occupant from Building M5, Stair 1 held people up during the stair descent between levels 3 and 0.

The occupant was female, middle-aged, obese, wore flat sandals, and held the handrail.

Stair Descent Schedules and Spread Sheets – Observations from Appendix A7.6

The only interesting observation for building M1 concerned the actions and descent characteristics of a morbidly obese female person carrying bags on her own. Others catch up from behind and do not pass but this impact is masked further by delays caused by the linking of the two stairs into a common passage. The average descent speed is 0.38m/s as compared with the Mature Age Focus Group of 0.36m/s. There was a certain degree of merging in distinct groups between levels 6 – 10.

There are no comparisons available for M2 because of the impact of the adverse conditions described in Chapter 4. There were two falls noted by observers. The first fall was an overweight male between 35 and 65 years of age from Level 34 who "haemorrhaged"[200] due to the excessive heat exertion and other factors and fell on the 10th floor. No further information was available from the paramedics who climbed the stairs to treat him and take him to hospital. The author was not permitted any further access. The second fall was that of a morbidly obese male with reduced vision, He descended from level 36 stopping to rest on two occasions. The fall (coming to rest on the ground) occurred on level 13. The fall was due to the male missing his footing due to lack of step definition, lack of strength due to fatigue to prevent the fall and problems with balance and depth perception.

The average descent speed for M3 was 0.68m/s and compared well with the BMI Benchmark Focus Group. Occupants with more than two health conditions and/or BMI>35 would have generally been at some risk of falling as this speed was > 0.36m/s the average speed of the focus groups with functional limitations. The observation of the delay caused by the family with two toddlers is confirmed by the average descent speed at this point which was only 0.38m/s.

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[200] There was no liability attached to this incident as the research group were merely observers at a standard building trial evacuation designed and organised by others.

Observed handrail use increased by 100% between Level 9 and ground. Some voluntary merging occurred at levels 16, 15, 11, 10, 9, and extensively at 5 and 3.

The average descent speed for M4 overall was 0.38m/s resulting from delays of up to 3.5 minutes due to merging between occupant groups on the lower levels. There was no significant relationship between density and velocity (R^2=.01). 83% of those observed were using the handrail. Many of the occupants observed held up the others behind and of those 16.7% were significantly overtaken (including the male of +60 yrs.). 58% of the occupants were of “normal weight” but held up others due to functional limitations or due to the wearing of unsuitable footwear (high heels). There was evidence of two occupants resting.

The average descent speed in M5 is 0.51m/s and density can only predict an average 30% of the variance in speed. There was extensive queuing in the stairs especially between levels 12 and 13. Delays also occurred due to merging initially up to level 11 and then to a certain degree in the levels above. 40% of the occupants observed were obese and most likely unfit. Others were slim and had some sort of functional limitation or wore unsuitable footwear. 90% of those observed used the handrail. There was a healthy distribution of slow movers especially in stair 2. Of special interest is a female descending from level 13 who after negotiating two flights rested on level 11 before assisted by two other females down to the ground floor.

Only 25% of the occupants in M6 were overweight and some of them were significantly overtaken. Others were mostly of normal weight and of these 50% were overtaken by others. There is evidence of resting although the space within the stairwell was minimal (e.g. female from level 27). Approximately 45% of those observed used the handrail. The average descent speed was 0.6m/s and is the same as the projected group speed of the BMI Benchmark Focus Group. The density varied from 0.5 – 2.6 persons/m^2 and yet the relationship cannot be positively confirmed as R^2 values varied from 0.02 to 0.42. The latter is most likely due to the impact of ascending three levels from the basement to ground level outside as well as the size of the groups and extent of merging between three sequential levels. A 60+ year old male was significantly overtaken by others. Approximately 42 % of those observed in Stair 2 were overtaken by others. 67% of the slow movers were female and of these 42% were under the age of 35 years. Approximately 20% of the female occupants observed wore high heeled shoes and relied heavily on the handrail.

BUILDING NUMBER	All OBESE classes BMI	BMI>35	Balance/Fear of Falling from Survey	≥ 2 Health Conditions	R^2	Masked by density
	% age population	% population	%age population	%age population	Average across all stairs	
M1	6.0	4.0	3.9/2.9	2	0.23	23% could have been masked – reduced stair width where scissor stairs link into common passage
M2	15.65	12.1	0.7/0.7	3.3	estimated	Not measured
M3	14.7	9.0	4.7/2.8	5.2	0.21	21% could have been masked
M4	3.4	1.1	4.1/13.4	3.3	0.01	
M5	7.4	1.8	6.9/6.9	5.5	0.3	30% could have been masked – delays due to extensive merging
M6	9.9	3.3	2.9/7.1	8.2	0.3	30% could have been masked – some delays due to 3 storeys of ascent

Table 7-28: BMI and Functional Limitation Falling Risk – Derived from Comparison with Fuller Figure and Mature Age Focus Group Benchmarks

Building No.	Range of Densities Persons/m^2	Estimated	Perception confirmed with density measure	Comments
M1*	0.4 – 2.2	3.9/69.2	48%	**"Few others around" only confirmed**. *The stair descent chart clearly shows the maximum densities at the lower three levels caused by the **reduction in exit width** and the merging pattern to proceed down a common corridor.*
M2 (sequential)	Not measured	42.5/50	Not measured	No comments
M3*	0.3 – 1.5	18.1/71.4	70%	**Across all responses** *Relatively low densities which is confirmed by the 71.4% response for the "few others around category". There was a marked difference between the two stairs which is reflected in the 18.1% for the "crowded" categories. Delay in one stair due to family with children and a pram from level 11 which caused stair to bank up slightly behind.*
M4*	0.2 – 1.7	2.1/67.7	89%	**No "crowded and slow" recorded** *Stair Descent Charts and observer comments show 13 occupants significantly holding up others behind due to assumed functional limitations and also unsuitable footwear (high heels). Also some 100 seconds where conditions on one of the stairs reflected the "alone" category between levels 18 and 11. Some evidence of overtaking. Generally when upper levels came in contact with the "tail" of the lower levels*
M5*	0.65 – 3.5	95/5	87%	**No "alone" and "few others around" recorded**. *This is the most significant triangulation as only two categories were recorded from the survey and these reflected exactly the data shown on the density/velocity charts over time.*
M6 (sequential)	0.5 – 2.6	83/15	30%	**Mainly verified in the "crowded and moving well" category**. *Velocity/Density Charts provide little information other than the high rate of group formation and the apparent size of those groups. Management would have organised the groups in terms of structure but they were also quite closely monitored by fire wardens keeping them close together and moving uniformly. An example of this is the interaction of wardens with a 35-59 year old male who was not staying within a group so that he did. Density in this situation is taken to be directly associated with the slow movers and group size. . .*

Table 7-29: Triangulation of "Conditions in Stairs" (Source: Appendix A7.6)

Descent Velocity Regression

The results of the regression analysis from the stair descent spread sheets may be found in Table 7-28 above. Where some relationship is achieved the velocity only accounts for 30% of the variance generalised across all samples. Seeing all stairs are less than 1000mm in clear width there is insufficient room for a great deal of overtaking. The results will be discussed further under "*Triangulation Schedules*".

7.6.4 Triangulation Schedules – The Individual and Groups

Table 7-28 and Table 7-29 demonstrate the following for M1-M6 via triangulation:

- M1, M3 and M6 show a consistent pattern between the risk of falling and obesity / functional limitations (calculated from Appendix A7.6). M4 and M5 triangulates with balance. The percentages of concern from the survey are small (1-9%).
- M1, M3, M4, and M5 show a strong pattern between those occupants with ≥2 health conditions and balance or stability going down the stairs. The same pattern is not reflected for the fear of falling except for M6 which was confirmed by the Focus Groups. It is assumed that M2 would follow M6 based on observers' comments. The percentages are in the same range as for the obese condition varying from 2% to 8.2%.

- Fatigue can be "masked" by density. The causal relationship between density and velocity is extremely weak and only moderately significant ($p<.05$ for M1, M3, M5 and M6) and yet delays caused by merging and the width of stairwell can have the same effect. Detailed comments are shown in Table 7-28. Nevertheless the descent speed of 0.39m/s for M4 indicates the cause is due to slow movers and delays.

The average descent speed for the Fuller Figure and Mature Age Focus Groups was 0.36m/s. The average descent speeds for M5 and M6 is 0.51m/s and 0.6m/s respectively which is within the projected average descent speed of the BMI Benchmark Focus Group of 0.6m/s as presented in Chapter 6,

- The generalised occupant estimated descent capability of 25 storeys in the 1980's as shown in Chapter 5, Figure 7-10 shows that the descent capability of 50.8% of the aggregated 2008-2010 case study population is 20 storeys or less.

In discussing the impact of group formation, size and cohesion it is necessary to triangulate the findings of the survey. Group formation triangulation is shown in the second left hand column of Table 7-29. The formation rate of 31.4% for M1 is confirmed for 47% of the time; the rate of 48.1% for M3 is confirmed for 60% of the time; the rate of 54.7% for M4 is confirmed for 80% of the time; the rate of 76.7% for M5 is confirmed by 96% of the observations and finally the rate of 67.3% cannot be reliably confirmed for M6 as the observations only accounted for 9% of the sample. 60% of the buildings were confirmed for more than 40% of the time. This is considered to be reliable especially when random observations by the M6 observation team from levels 31, 25, 20, 16, 10 and 3 confirm the survey response rate of 67%.

Table 7-28 does show a weak causal relationship between velocity and density. When the density patterns over the evacuation period across buildings taken over the evacuation period as shown in Table 7-29 are compared (see Appendix A7.6 for actual patterns) it could be concluded that there is some kind of relationship. This is not supported by the regression analysis. It is also not supported by the stair descent charts. An in depth analysis of the spread sheet data and embedded observations show that there are extensive delays due to merging, group size and the narrow stairs prevent extensive overtaking. It estimated that if these effects were included that up to 60% of the variance could be predicted. A significant relationship between those factors that reduce the descent velocity could be loosely represented by density if delays, group effects, and exit configuration were included. Based on output and analysis of the focus group data in Chapter 6 and Appendix A6 a reduction in the descent rate is directly related to "estimated capability" where the risk of falling and fear of falling and crowds are concerned.

The relationship between "density" and "velocity" was measured via regression but there is still a need to triangulate these results with the perception of the occupants. M1 occupants did not really register the delays at the lower levels caused by the common corridor as 48% of the confirmations related to a "few others around". M3 shows relatively low densities (0.3-1.5 persons/m^2) which is confirmed by the 71.4% response for the "few others around" category. There was a marked difference between the two stairs which is reflected in the 18.1% for the "crowded" categories. The M4 Stair Descent Charts and observer comments show 13 occupants significantly holding up others behind due to assumed functional limitations and also unsuitable footwear (high heels). There is some 100 seconds where conditions on one of the stairs reflected the "alone" category between levels 18 and 11. No "crowded and slow" responses were recorded which reflect the range in measured densities (0.2-1.7 persons /m^2) so that the confirmed rate of 89% is positive. The M5 densities range from 0.65 to 3.5 persons/m^2 are confirmed at the rate of 87% across the categories of "crowded and moving well" and "crowded and slow" categories. The M6 densities range from 0.5-2.6 persons/m^2 with an average descent velocity of 0.6m/s so that the survey rate of 30% which is confined mainly to the "crowded and moving well" category is reasonably reliable.

7.6.5 Triangulation/ pattern matching between STAIR and Individual Functional Limitations.

The aim of the PhD Case Study is to examine an occupant's estimated descent capability in the context of the critical factors in each of the core consistencies. Estimated capability is measured in the number of levels descended. The Delphi Group was not convinced that this measure should be established by a self reporting procedure so that some triangulation is required between a measured figure and a self reported figure. There may not even be a relationship between the two. Another self reporting measure that correlates significantly with functional limitations and the level of fitness is whether or not an occupant agrees that there are too many flights. The latter has therefore been triangulated with a measured figure as well. The measured figure is the floor of evacuation which is an approximate measure of the actual distance traversed. The value of this triangulation is that it can be related to the outcome of the correlation and factor analysis in this Chapter.

Building	Mean Evacuation Level/	"too many flights" (% agree)	Mean Estimated capability (no. levels)
M1	**5**	**8.8**	**14**
M2	**20**	**46.1**	**21**
M3	**8**	**10.6**	**17**
M4	**11**	**10.4**	**29**
M5	**10**	**6.8**	**17**
M6	**15**	**30**	**30**

Table 7-30: Triangulation Schedule for Descent Ability

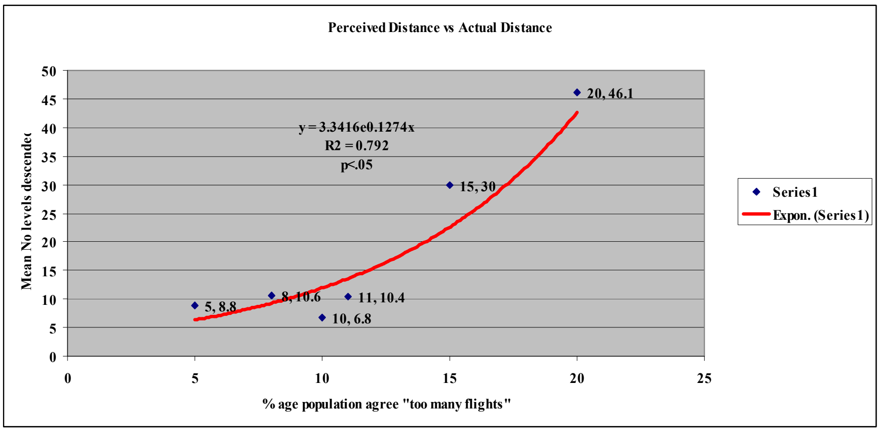

Figure 7-16: Percentage "too many flights" vs. Mean Actual Distance (No. of Levels)

Figure 7-16 shows that the line of best fit between an occupant's mean estimated journey of descent as represented by "percentage too many flights" and the floor they started their evacuation from is an exponential relationship where:

Y (mean number of floors descended) $= 3.341e^{0.1274x}$ *where x = "too many flights –agree"*

The triangulation accounts for 79.2% of the variance and is moderately significant for $p<.05$.

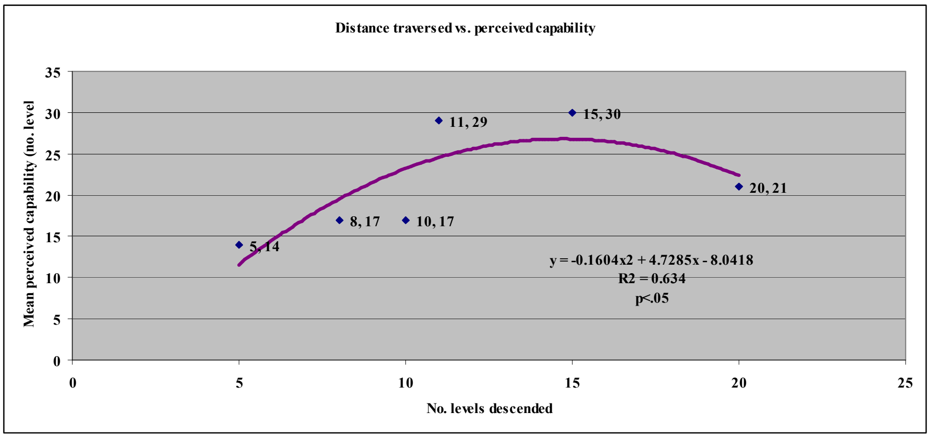

Figure 7-17: Distance traversed vs. Mean Estimated Capability (No. of Levels)

Figure 7-17 shows that the line of best fit between the mean estimated capability and the distance that they actually descended (both measures are the mean) is a polynomial relationship where:

Y (mean estimated capability – no. of levels) $= -0.1604x^2 + 4.7285x - 8.0418$ *where* x *= no. of levels descended.*

The triangulation here only accounts for 63.4% of the variance and is moderately significant for $p<.05$.

The value of this analysis is that "too many flights" correlates moderately significantly ($p<.05$) with the following intrinsic factors which can be classified as being directly associated with descent risk as an outcome of the factor analysis summarised in Table 7-26 and Table 7-27

- Fatigue (reasonably significant for all buildings)
- Pain in lower limbs (reasonably significant for all buildings)
- Asthma / dyspnoea (reasonably significant for all buildings)
- Balance/ dizziness/ agoraphobia (reasonably significant for M1-M4)
- Chest discomfort (reasonably significant for all buildings except for M3)

Triangulation therefore confirms that fatigue relates directly to distance (estimated and measured) and is the most critical intrinsic factor underpinning an occupant's estimate of their descent capability. Chapter 7 shows elsewhere that falling risk is also linked indirectly with fatigue so that it also underpins estimated descent capability.

7.7 Conclusion

A similar response for the Exploratory Case Study, Content Analysis and Focus Group Studies may be found in Chapter 6. The purpose of this section is to draw together the results and discussions centred on the 2008-2010 Case Study. This conclusion links to the findings in Chapter 8.

7.7.1 The Aim and 2008 – 2010 Case Study

The Aim of the PhD Study once again is:

"*To study the performance of mature office workers in trial evacuations of high rise office buildings in the context of extrinsic and intrinsic factors*"

Age cannot be generalised as a significant predictor of fitness or obesity. The "crosstabs"[201] analysis in Table 7-12 did show a more predominant distribution of morbid obesity amongst the mature age office workers (>45 years) which is confirmed in other general population based studies (Mchurchu et al, 2004; Bertrais et al, 2005 and Jia and Lubetkin, 2005). Age is therefore still seen as being associated with fitness in terms of the loss of strength (muscle mass) after the age of 40 years (Lauretani et al, 2003). The reduction of the descent speeds of the Fuller Figure and Mature Age Focus Groups below that of the BMI Benchmark Group coupled with their comments show that there is some kind of relationship especially when this lack of fitness is associated with functional limitations (Booth et al, 2002).

Taking the above factors into account the main response to the Aim is that 50% of the general population as represented by the mean of the occupants from M1-M6 do not believe that they can cope with more than 20 storeys as predicted by the expression y (cumulative percentage of population) = $-0.017x^2+2.7449x-5.7391$ where x= the number of storeys or levels. Triangulation also revealed:

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[201] "Descriptives" – SPSS V16

- That the distance actually travelled could be used to predict the occupant's estimated capability with a variance of 63.4% ($p<.05$)[202].

- That the fatigue and "fear of falling" related response of "too many flights" for 50% of the population could be used to predict the number of levels actually descended ($R^2=.792$, $p<.05$)[203].

Distance is also shown as a major predictor of travel speed (Peacock et al, 2009 and 2012) and this supports the above. Table 7-28 and Table 7-29 showed that there was no pattern associated with descent speed as a predictor because of the masking effect of density, delays and narrow stairs. This was explained further by the Fuller Figure and Mature Age Focus Groups where they said that as individuals they often descended at a faster speed than they were comfortable with because they were too embarrassed to ask the rest of the group to slow down. They maintained that this increased the falling risk. Table 7-28 and Table 7-29 show a weak pattern appearing between the number of levels traversed, descent speed and the estimated risk of falling based on the Focus Group explanation.

7.7.2 Specifics on triangulation

Distance and Descent

After reducing the number of variables from both the survey and the measured data by factor analysis and then triangulating the results the two main factor groupings are "Degree of Descent Comfort" and/or "Descent Risk" especially with the highly significant relationship between estimated distance and fatigue in Table 7- 10 ($p<.001$). The other is Visibility and Support. The groupings partly

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[202] For the expression y (mean estimated ability in no. of levels) = $-0.1604x^2+4.7825x - 8.4108$ where x= no. of levels descended by 50% of the population from M1-M6.

[203] For the expression of y (mean number of actual levels descended) = $3.3416e^{0.1274x}$ where x= "too many flights' for the mean population of M1-M6.

agree with other studies (Wright and Roys, 2008 and Johnson and Pauls, 2011) except that distance is added[204].

Functional abilities

The Exploratory Case Study revealed a significant concern to evacuating occupants ($p<.01$) and that was the effect of "perceived" locked exit doors. This triggers a possible fear known as agoraphobia in occupants with anxiety disorders and can manifest in various forms especially dizziness and vertigo (NCBI, 2012). Health conditions or functional limitations[205] together with obesity/ fitness are therefore the critical factors that could trigger a fall. These factors are corroborated by the significance of their relationships to fatigue ($p<.01$) in Table 7- 10 and the relationship of fatigue to estimated distance ($p<.001$).

The literature shows that walking speed can be used to predict functional limitations (Fritz, 2009 and Spearpoint and MacLennan, 2012) and yet this could not be confirmed through extensive triangulation in Section 7.6. It was confirmed in the Focus Group Studies as shown in Chapter 6 where the speeds of those with functional limitations are compared with those in a Benchmark Group of fit young office workers.

Validated measure of fitness – any change from BMI measure?

Regardless of the reporting instruments used[206] the level of significance associated with fitness was still only moderate. In attempting to generalise between building populations the data was aggregated for M1-M4 and M5-M6. The correlation was still moderately significant ($p<.05$) but R increased from

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[204] Once again supported by Focus Group Comments of the "downward spiral".

[205] Dizziness/Vertigo/Balance, Lower Limb pain and strength, respiratory conditions, and fear of crowds and falling as well as those factors that increase fatigue as a function of distance travelled.

[206] The validated IPAQ system for M5 and M6 only slightly improved the correlation between fitness and estimated descent capability.

0.177 to 0.35. The constructed variable "METS" (combination of no. of health conditions and BMI) for M1-M4 followed the same trend (R= 0.4) being moderately significant. The only response to RQ3 is that IPAQ does not decrease the level of reliability.

The survey data and Delphi opinion on stairs

The factors raised by the Delphi Group and in the literature review for the measured assessment were reduced by factor analysis. There were a total of 6 principal components produced (SPSS V16) with *eigenvalues* > 1. The cut off value for factors clustering around each of the components was >0.7 which is conservative (Child, 2006). Linking components 1-3 together matched the outcome of the factor analysis of the equivalents from the survey respondents. The two groups represented Descent Risk or Degree of Descent Comfort and Visibility/ Support. This reduced variable correlated highly significantly with estimated descent capability for M1-M4 combined (n=326) with R=0.59 and p<.001 and for M5-M6 combined (n=232) with R=.285 and p<.001.

Modifications to STAIRS – focus group and survey

As a result of the Focus Group suggestions and Section 7.6 the modifications required are:

<u>Stair comfort to create confidence or decrease descent risk</u>

- 300mm goings corroborated by the mean shoe sizes determined of between 280-300mm and their association with occupant concern in the survey.
- Stair pitch being in the preferred zone of between $23^0 – 32^0$
- Uniformity with construction tolerances as specified of 5mm maximum.
- If some variance is to be accepted then two handrails should be provided within reach as evidenced by the need in Appendix A7.5.

- Number of turns kept to a maximum of two per level. The well void should be such as to avoid the user being distracted by views of lower levels.

- Stairwell should be properly maintained by management so as to be free from obstructions, irregularities and surfaces that have a Pendulum Test Value less than 36.

- Levels should be clearly marked and doors provided with viewing ports.

- Nosings should not promote injury[207].

- Nosings should be clearly marked in contrasting colour (contrast sensitivity >0.3)

(Refer also Roys, 2006; Alderson et al, 2010; Templer, 1992; Pauls et al, 2007)

Visibility and support:

- Resting space every five floors as detailed in Chapter 6 or provide wider stair between 1200-1500mm between walls which would not only cater for counterflow and overtaking but would also provide resting space. This requirement is also confirmed by the number instances of overtaking in M5 and M6 that alleviated frustrations of some with slow movers. Additional space would address needs of occupants who became anxious during descent because of a fast descent speed (refer Pauls et al, 2007 and MacLennan 2011).

- Handrails should be continually graspable (32-45mm diameter) and be of a contrasting colour.

[207] Sharp steel edged nosings can cause injuries compared to nosings that are "pencil" rounded.

- Vertical and horizontal surfaces should contrast in colour so as to increase the legibility of the steps.

- Doors should be recessed and sighted so that flows are not diametrically opposed; this allows for smoother merging.

- Illumination should clearly define the steps for each full flight without creating glare or shadows. This aspect must be maintained as made very clear in the Exploratory Case Study.

- Conditions must be adequate so as to avoid heat building up and lack of air. Mechanical ventilation is vital and must be maintain especially to operate in evacuation mode (M2 survey results and observations confirm this especially with the evidence of two falls).

Self designation in evacuation planning

Self designation is appropriate as evidenced from the Chapter 6 Content Analysis of Dwyer and Flynn (2004) by the actions of the female who organised her own evacuation chair and buddy group who were trained. Zmud (2007) shows how this approach was successful without compromising others. Self designation is appropriate but can only be encouraged using a system such as PEEPS (DCLG 2007a) where the management team is inclusive (Gwynne, 2008). The Focus Groups recommended this approach and such a system is part of the procedures for M6.

One important thing to realise is that the evacuation strategy can increase the falling risk as is evidenced in the difference between uncontrolled and controlled evacuations. Section 7.6 shows that descent speeds usually increased with sequential evacuations for buildings such as M6 and also Building 7. This can be seen in a comparison between the stair descent graphs for M4/M5 (uncontrolled evacuations) and M6 in Appendix A7.6. Uncontrolled evacuations are usually more efficient except that there will be more delays due to merging which generally is the result of deferment (also refer stair descent graphs and observation schedules in Appendix A7.6). Uncomfortable descent speeds make users less confident as confirmed by the Fuller Figure and Mature Age Focus Groups in Chapter 6.

Risk to the Group of providing assistance

An author based case study described in Section 7.5.3 in assisted evacuation that tested the outcome and assumptions of a study by Adams and Galea (2011) confirmed that a group of two persons could assist a 200Kg occupant down a $+37^0$ stair with an average descent speed of 0.5m/s which is the same as measured in M5. Discussion of this study in Section 7.5.3 reveals that as many as eight individuals may be required to assist such an individual. They may not be trained to do so and therefore may injure themselves. This is also backed by other similar handling studies such as that by Hignett et al, (2007). The WTC9/11 Incident Content Analysis in Chapter 6, the report by Zmud (2007) and the Author's evacuation chair case study shows that there are devices, which, if used by trained individuals in an organised group, can easily mitigate this hazard and that it can be inclusively organised.

Fear of the group by its members

The threats to individual descent capability (actual and estimated) identified by the Focus Groups in Chapter 6 and triangulated further in Table 7-28 . The individual may be too embarrassed to step out of the group and rest as did some of the occupants in M6 especially where the stairs are not wide enough. The result is that occupants who have an increased risk of falling due to obesity and other associated health conditions including anxiety disorders will be further threatened when descending at a speed with which they are uncomfortable.

- Members of the group will most likely wish to help (102 Minutes Content Analysis) and yet might not be trained to do so. Tasks such as the manual lifting of a morbidly obese person can cause problems (Signet et al, 2007) and may require more than one person (Adams and Galena, 2011).

- Groups are readily formed for 87.5% of M1-M6 matching the findings from the Exploratory Case Study (see Chapter 5).

- The Fuller Figure and Mature Age Focus Groups showed that occupants or individuals can be apprehensive about others in the group due to "fear of crowds" (highly significant - $p<.001$, M1-M6, (Table 7-10) e.g. view of steps obstructed by others in close proximity.

- The NY Times Blog Content Analysis (Parker-Pope, 2008 and Pull, and Heber, 2009) demonstrated some antagonism toward to obese persons who were slow movers.

- Uncontrolled evacuation strategies may increase the densities and momentary delays in the stairs but will reduce the descent speed but this will decrease the amount of fatigue as individuals will have time to rest. Sequential evacuations may result in faster evacuation speeds but may place some at risk who are obese and/or subject to other functional limitations by increasing the risk of falling.

7.7.3 The Contextual factors:

This section should be read in conjunction with Figure 7- 18 where the status of the contextual factors is summarised on the fins of the chart linking in with the spine.

The Individual (Intrinsic):

Age and gender have no significant relationship to performance that can be generalised across the cases other than when related to fitness and functional limitations though age and gender as shown in the Chapter 6 studies.

Obesity and fitness including that measured using the validated IPAQ tool were moderately significant in terms of performance. When linked with functional limitations such as diabetes, balance, cardio vascular conditions and other as highlighted by Booth et al (2002) the level of significance was high when compared with estimated maximum distance descent ability or actual number of storeys traversed. Other cognitive and neurological conditions such as fear of falling, agoraphobia and other anxiety disorders limit performance in a highly significant manner.

Fatigue relating to fitness and other conditions is able to predict performance more so than any other intrinsic factor. This relationship was found for both the estimated and actual performance. This was also confirmed through triangulation.

The stairs – environment and construction:

Factor analysis reduced the variables to:

- Descent risk/ hazard/ comfort: made up of pitch, tread width, number of turns, and distance traversed including width of well (distractions)
- Visibility and support made up of stair width, handrails, legibility non slip surfaces, ventilation and illumination.

There is a highly significant relationship with performance. Triangulation with survey respondent reaction to this classification supports the results and also compliments the work of Johnson and Pauls (2011) especially in relation to pitch. The results through triangulation agree with findings of Reeves et al (2008a) of increased individual confidence in terms of individuals being just able to “run their hands along the handrail”. The significance of ventilation and illumination is maintained between all the studies from Chapters 5-7.

The author case study on the Christchurch earthquake evacuation shows the dichotomy of increasing the width of stairs. This compromises some individuals who require the use of two handrails when resting spots are not available. The author was a slow mover and held up the others.

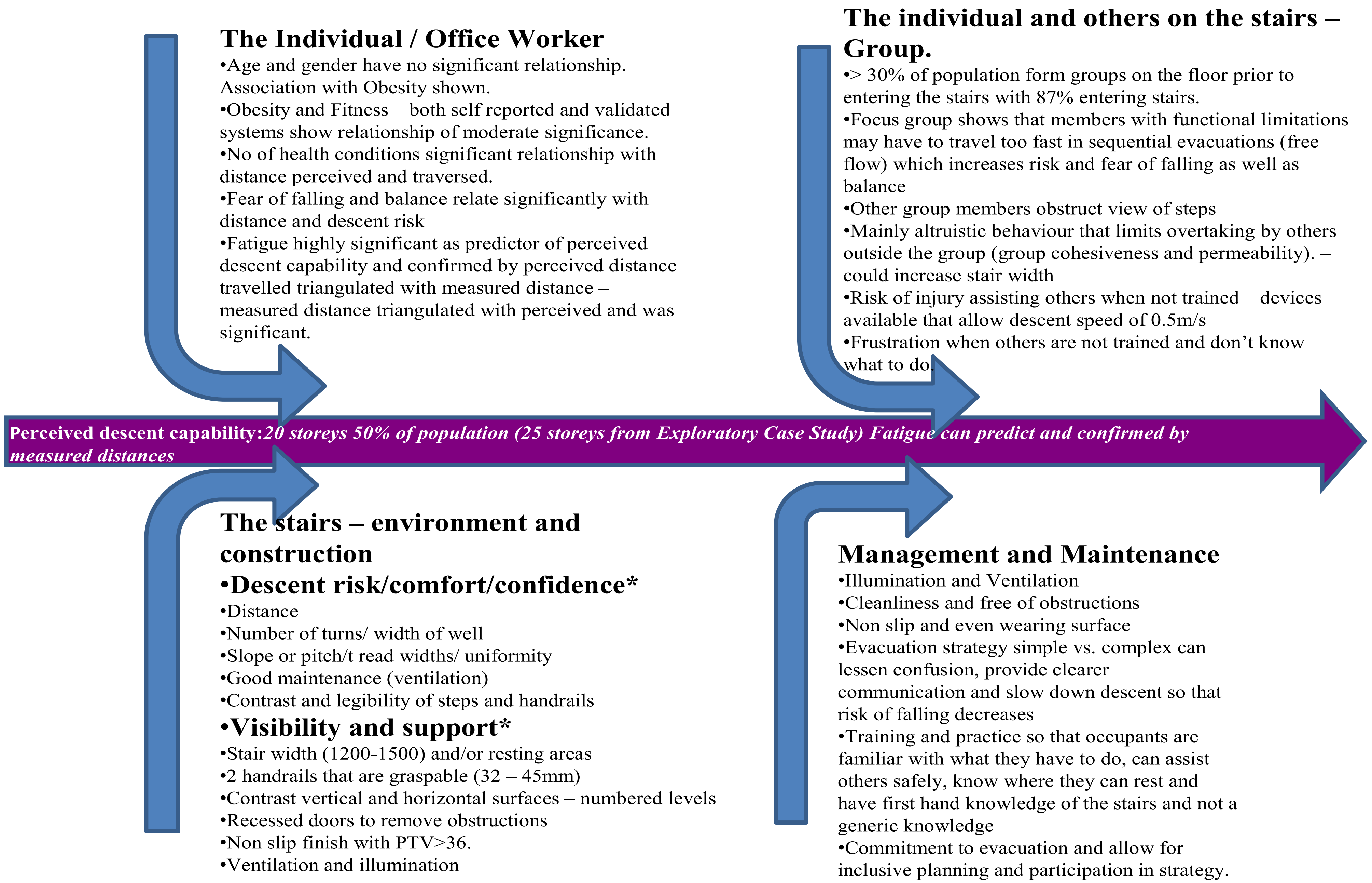

Figure 7- 18: Ishikawa Chart Summary of significant contextual factors and main indicators of descent capability or performance

The Individual and others (Group) on the stairs:

Over 30% of those entering the stairs do so in groups. This can be clearly generalised between the buildings and is common to both the Exploratory case study and the 2008-2010 case results. There is a significant percentage of the population exposed to the risk of injury when assisting others when they are not trained to so. The results of the author's assisted evacuation study show that training is essential when moving the morbidly obese mobility impaired person and that the resultant descent speed of 0.5m/s would not have caused a delay in the M1-M6 evacuations. This shows that the assisted evacuation case study is a valuable triangulation tool.

The Focus Groups made the point of others in descent groups obstructing the view of the steps which affected safe foot placement and decreased the individual's descent confidence. The same Focus Groups also mentioned that they were embarrassed as slow movers to ask others in the descent group to slow down. The resultant descent speeds from the Focus Group tests when compared with those on the stair descent charts for individuals with similar intrinsic characteristics showed that these people would be more susceptible to falling (Mademli et al, 2008).

Group cohesion was confirmed in Chapter 6 as the predominant group dynamic from the Dwyer and Flynn study (2004) and yet opposite behaviour could be expected as seen in the NY Times Blog study (Parker-Pope, 2008). This aspect is seen as being of interest when triangulated with the high rate of group formation (>30%).

Management and Maintenance:

Maintenance was found to be highly significant right through all the studies in Chapters 5-7. The results from the Building M2 evacuation show what happens when ventilation is absent and conditions become very difficult. Illumination is also just as critical as the lack thereof will reduce descent speed and confidence. Cleanliness of stair environments can be linked to maintenance.

This means that a good maintenance strategy underpins a safe and sound evacuation plan.

Comparisons between the buildings show that a simple uncontrolled evacuation plan is perhaps the most suitable. There are normally more people in the stair at any one time (e.g. building M5) and the resultant density and other delays due to merging slow the rate of descent down so that people do not have to hurry. The risk of falling is reduced.

Training and regular drills show up in the results especially when further explained by the Focus Groups. It also means that participative and inclusive planning can take place and that assisted evacuation is possible without slowing others down (author's assisted evacuation study and confirmed by the Dwyer and Flynn study (2004) which is also confirmed by Zmud, 2007). Assisting others safely can be included as part of the plan at evacuee level (Zmud, 2007).

Overall commitment to evocation safety is essential as confirmed by the Focus Groups and a comparison of the M1-M6 trial evacuation results e.g. M5 vs. M2.

7.7.4 Summary for Findings

Findings are presented in Chapter 8 and will combine the outcomes from the Results and Discussion Chapters 5-7 and the above conclusions in this section.

Chapter 8: Conclusions and the Future

8.1 Introduction

The study described in this PhD Thesis is one concerning the descent performance of individuals on multiple flight stairs in high rise office buildings in the context of the various intrinsic and extrinsic factors that may impact on or define this performance. The subject is complex as shown in the Literature Review in Chapter 2. A multiple case study approach was selected designed in accordance with the guidelines set down by Yin (2009) and Gray (2009). The method was described in full in Chapter 3 and arrived at by peeling away the various layers of research onion as described by Saunders (2007).

An Exploratory case study involving the reanalysis of a trial evacuation study undertaken in 1980 revealed that there was a further need to repeat and enhance the previous 1980 study by repeating the exercise in the current decade and using additional explanatory studies comprising:

- The content analysis of the WTC 9/11 incident to explore the origin and context of fatigue.
- The content analysis of community attitudes on fitness and multiple flight stair descent.
- Delphi group study to define the context of multiple stair descent and possible ways of measuring or describing it.
- Three focus group studies where one of the focus groups represented a group of “fit”[208] office workers and the other two with one of office workers who were either unfit with functional limitations and the other office workers over the age of 45 years of age.

The explanatory studies and the 2008-2010 trial evacuations formed what has been described as the 2008-2010 case study, the results of which are

[208] Fit as described by Ottevacre et al (2011).

presented and discussed in Chapter 7. They were also compared with those findings from the Exploratory case study to determine in the main whether or not descent capability or performance had decreased over the last thirty years. The Explanatory studies helped to explain may of the rival theories that arose during the study such as the relationship between fatigue and density (Galea et al, 2011 and Spearpoint and MacLennan, 2012).

This Chapter is used to present the findings from this multiple PhD Case Study in the following format:

- Summary of main findings
- Delivery of the Aim and Objectives (O1 to O4).
- Findings derived from causational or triangulated relationships.
- Other contextual findings which are of moderate or low significance but which can still be further explained by triangulation or the Explanatory studies.
- Limitations of the Study
- The future

All in all this PhD Case Study has been a challenging one in which longitudinal relationships have been established as it has been possible to generalise between the Exploratory and 2008-2010 case studies and also rival theories that have arisen can be explained by the contextual nature of the overall case study.

8.2 Summary

A seminal engineering science paper written by Pauls, Fruit and Zupan, (2007) stated unequivocally that because the population was ageing and decreasing their amount of physical activity their level of obesity and related functional limitations was increasing, thereby decreasing their ability to descend stairs as part of the required training programmes in high rise office buildings. The decrease in fitness and the associated metabolic problems was also backed up by a seminal health science review of the impact of the decrease in physical activity by Booth et al (2002). The PhD case study supports these assertions via a contextual study which clearly shows the impact of functional limitations and distance traversed on descent capability or performance. The descent capability of 50% of the population in the 1980's was some 25 storeys or approximately 250m as compared with 20 storeys or approximately 200m in 2010. This is a decrease of some 20%.

The results also confirm an increase in the risk of falling as a function of distance traversed which correlates with fatigue. Generalising between the Exploratory and 2008-2010 case studies (Yin, 2009) the increase in the risk of falling can also be attributed to the claims made by Pauls, Fruin and Zupan (2007). Lord et al (2006) confirm that as people tire they are more prone to falling. Madelmi et al (2008) also attribute falling to hurrying. This was supported by triangulation between the distance traversed and the descent capability available from the 2008-2010 trial evacuation data and explanations from the focus group responses and tests. It was a simple matter that a group member is usually too embarrassed to ask the other members in their group to slow down when descending the stairs. They hurry to keep up, tire more easily, and their level of stress increases which is attributed to a lack of confidence or fear of falling. The risk also increases because the other members of the group may obstruct a clear view of the steps which adds to the chance that the individual may lose their footing and fall. This is of concern when the rate of group formation generalised across buildings M1-M6 is greater than 30% which is more than the findings of Boyce et al (2011).

The impact of the group on the individual with functional limitations or perhaps an anxiety disorder[209] that can manifest itself as vertigo (NCBI, 2012)

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[209] Known as agoraphobia (NCBI, 2012) and also confirmed as contributing to the falls in Building 4 of the Exploratory case study and in M6 in the 2008-2010 case study. Also stated as a fear in the 1977 Canadian Study by Beck (1977) in Chapter 5.

can be mitigated by the evacuation strategy. In the case of an uncontrolled evacuation where everyone leaves at the same time the density or number of people in the stairs is such that the descent speed is reduced. There are also an increased number of delays which means that the evacuees have more time to rest and also go down the stairs at a more comfortable speed. Fatigue here may not be an issue which shows up in the pattern across the triangulated results of M1-M6 in Chapter 7. M5 showed a reduced frequency of fatigue which triangulated with an increased density and reduced descent speed (see also stair descent chart in Appendix A7.6). This example of a result solves one of the rival theories where distance may not result in fatigue as shown by Galea et al (2011) as it is masked by density (Spearpoint and MacLennan, 2012).

This introduction to the findings shows the value of the contextual study of individual stair descent capability or performance in high rise building office buildings. Both Gray (2009) and Yin (2009) support the use of the case study method when the context surrounding the performance of an individual is required to explain that performance (individual is the "unit of analysis). The selection of the case study as the research method in Chapter 3 therefore assisted greatly in delivering the aim of the PhD Case Study being:

. "To study the performance of mature age office workers descending multiple flights of stairs in trial evacuations of high rise office buildings in the context of extrinsic and intrinsic factors

8.3 Was the Aim Delivered?

Section 8.2 provides examples of the Aim being delivered especially in terms of the longitudinal change in the estimation of descent performance and capability justifying in part the claims made by Pauls, Fruin and Zupan (2007). The one surprising finding is that over the six buildings studied in the 2008-2010 case study, age was found not to be a predictor of performance[210]. This finding

[210] No significant correlation relationships were found either as shown in the Correlation matrix in Chapter 7.

can be generalised (Yin, 2009) as it follows a similar pattern (Hak and Dul, 2009). The author had a similar preliminary finding on a study of older people climbing outdoor steps[211] where the number of falls increased amongst the younger age groups i.e. < 75 years. In this instance the older age group actually comprised people who were fitter than their younger counterparts. This does not hold true for older people and indoor falls[211]. The above finding contradicts the findings of Al-Abdulwahab (1999). A small cross sectional study of office workers in Europe shows that regardless of the individual's occupation sedentarism[212] during leisure time is high. The same study shows that sedentarism and therefore obesity increases with age. The differences can most likely be attributed to contextual factors. The explanatory focus group studies reveal further information. The Benchmark (fit) group descended at a speed of between 0.6m/sec to 1.2m/sec whereas the other two groups travelled at a reduced speed of between 0.28m/sec to 0.36m/sec. The cause of the reduction had more to do with an increase in functional limitations. The conclusion that could be drawn is that age is not a direct predictor of descent performance but is rather associated with an increase in functional limitations or increased physical inactivity (Booth et al, 2002).

The aim did nominate that the "critical" contextual factors would be determined. The significant factors are listed under each one of the Core Consistencies in Chapter 7. The relationship of each one of the factors to an occupant's estimated descent capability varies in significance from moderately to highly significant so that the pattern of the impact varies. The resultant patterns from correlation matrices are of interest. Most of these relationships are not causational except for the global survey response of "too many flights". This measure correlates highly[213] with distance travelled which is provided by the

[211] MacLennan et al (2011a)

[212] i.e. where a person's level of energy expenditure is less than 4 METS.

[213] R=>0.6 and p<.001

response concerning the floor they commenced the evacuation from (buildings M1-M6) so that the relationship can be generalised. Fatigue also showed the same relationship for M1-M6 ($p<.001$):

- Pain/ arthritis in knees and lower leg
- Dyspnoea/ asthma
- Chest discomfort
- Dizziness/ vertigo/ balance

Fitness / BMI only correlated significantly when the data was aggregated for M1-M4 and M5-M6. It is also well known that an increased exercise regime for mature age people can offset fatigue to a certain extent[214] so that activity, fitness and fatigue are related.

Chapter 7 also shows up the significant extrinsic factors related to the "STAIRS" as being descent risk and visibility/ support. These groupings are supported by agreement between analysed survey and measured data especially in terms of the most significant being narrow treads[215], stair pitch[216] and distance[217]. The cause of any fall is due to any number of contributing factors comprising a scenario. One of the M2 fall scenarios is used as an example that explains the value of contextual research. The treads were 300mm wide but there

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[214] Holloszy et al (1995) where the benefit of strength training is discussed as a fall risk reduction tool for the mature to old person.

[215] Foot size comparisons are shown for M1-M6 where the degree of overhang for sizes greater than the mean exceeded the tread measurement – Chapter 7

[216] Johnson and Pauls (2011) discuss impact of pitch. An equation was derived in Chapter 7 for tread widths of ≥ 250mm. The level of risk is generally less than .012 and increases rapidly when widths are < 250mm as is the case with M3.

[217] Peacock et al (2009) show that as distance increases descent speed decreases. Ayis et al (2007) confirm that descent speed is directly linked to functional limitations.

was no step definition. The traversal distance was some 34 storeys. The individual had reduced vision. He complained of fatigue and pain in his lower limbs. It was almost as if his legs could no longer support him at the lower levels and this was echoed by the Focus Groups in Chapter 6. Failure to detect the position of the intermediate landing caused the individual to slip or misstep and fall. This scenario is enhanced by survey responses from M2 showing that over 40% of the occupants thought that the stairs were too steep. Falls can be attributed directly to fatigue and loss of focus (Lord et al, 2006). The loss of stability control in forward falls is described in many studies as summarised by Mademli et al, (2008) is directly related to distance and fatigue but takes into account other extrinsic factors. If the branches of the Group and Management are taken into account then the M2 scenario is further complicated by a fast moving group and a sequential evacuation strategy. The individual in the fall was unfit, obese, and descended at an uncomfortable speed to keep pace with the group. There were only a few others in the stair so that density did not slow down the group. All these factors taken together contributed to the fall. The loss of stability in the second fall was triggered by hypertension and the excessive heat conditions and exacerbated by fatigue/ distance. The third fall was in M6 triggered by an anxiety disorder[218]. The individual fell and then would not move. Although the anxiety disorder was always present the distance, fatigue and other extrinsic conditions (especially the continuous downward spiral and the locked entry doors) exacerbated it. This fall replicates an identical scenario in Building 4 analysed in the Exploratory Case Study. Overall then the most significant of all the contextual factors as discussed in Chapter 7other than fatigue for the aggregated data (M1-M4 and M5-M6) are descent risk / stair comfort and fitness. Management and Group impact in various ways as per the fall examples for M2 and M6, so that the finding that ≤ 50% of the population do not estimate that they

[218] Agoraphobia is the disorder and presents to others in the form of vertigo and/or dizziness (NCBI, 2012) and Canadian Content Analysis (Beck, 1977) in Chapter 6.

can cope with than 20 storeys is an expected outcome that corresponds with a generalisation across M1-M6. The latter also relates well to the 25 storey limit for the 1980's for a similar range of office buildings determined in Chapter 5.

8.4 What are the significant findings?

8.4.1 The meaning of significant

The meaning of significant in this PhD Case Study is where highly to moderately significant relationship established in the analysis of survey data triangulates with observed and/or measured data. The quantitative analysis did not paint the total picture so that relationships established by regression and correlation were quite often found to be only moderately significant. Because the pluralist research approach was adopted it was possible to comment on the level of significance utilising output from the Focus Groups and Content Analysis Studies. This applies especially to the following:

- Fuller Figure and Mature Age Focus Group comments relating to increased risk of falling with fast descent speed when the individual member concerned was too embarrassed to ask others to slow down and there were no places to rest (narrow stairs).
- Evacuation strategy possibly determining delays, density and group distribution on stairs that could slow the descent speed.
- Evacuation training increasing the familiarity of individual occupants with the specific stairs.

The above was used to demonstrate the increase in the risk of falling as a function of actual descent speed, an approach supported by other health science studies[219]. This demonstration is therefore made possible by the selection of the research method. A finding is also said to be only significant if it can be

[219] Ayis et al, (2007)

generalised across all the buildings or in the instance of the aggregation of data comparison with the dataset analysed in the Exploratory Case Study (1980's data).

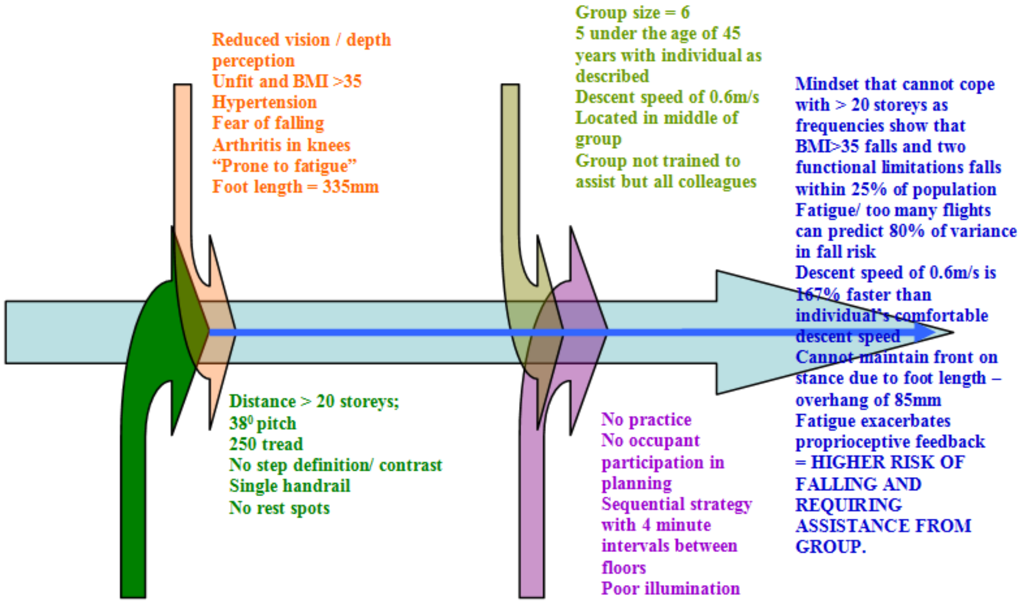

Figure 8-1: Example of how factors combine to increase risk of falling and decrease occupant estimated and actual performance[220].

The meaning of significant[221] is demonstrated by applying significant causational findings (fatigue and distance) within a context of significant factors to assist with the interpretation of a scenario as per Figure 8-1 above. The findings are therefore presented in order of significance as follows:

- Achievement of Objectives (Aim and Research Questions are addressed in Section 8.3).

[220] How a "cause and effect" or Ishikawa Chart (Portwood and Riesing, 2007) show that the factors listed on the "fins" interact on the spine influencing or directly causing the increase in falling risk on the spine. This type of approach is used by health and safety experts in incident analysis.

[221] Not just a "p" value

- "Spinal" findings (i.e. those with causational relationships that impact on actual or estimated descent capability – "spine" is highlighted in blue in Figure 8-1).
- Highly significant correlational findings
- Reasonably significant correlational findings
- Moderately significant correlational findings.

8.4.2 Achievement of Objectives

There are a total of four objectives. This section comprises the responses to each one.

Objective O-1

Establish which are the main extrinsic factors or core consistency in terms of their "measured" impact on an individual's performance.

The main extrinsic factors that can predict an individual's estimated descent capability are:

- Distance by pattern matching of frequencies with the same trend measured and triangulated in the Exploratory and 2008-2010 Case Studies. Falls occurred where distance exceeded 20 storeys[222].
- Descent Risk / Stair Comfort[223] ("downward spiral") being groupings created by Factor Analysis from survey responses and measured data and confirmed via triangulation and Focus Group consensus.
- Group dynamics and evacuation strategy resulting in free flow/ velocity. Groups could descend at speeds of ≥ 0.5m/s (0.6m/s-1.2m/s range for fit benchmark focus group). Individuals who were unfit and/or had more than one health condition would have been uncomfortable at this speed and yet too embarrassed to ask the group to slow down[224]. This finding was triangulated via a comparison between individual focus group

[222] Established via regression analysis for ≤ 50% of the population and generalisation across M1-M6

[223] Note that equation derived from Johnson and Pauls (2011) in Chapter 7.

[224] Confirmed by Fuller Figure and Mature Age Focus Group consensus in Chapter 6.

members[225] so that risk of falling could be established and compared with stair comfort results. High level of significance (correlational) was achieved (p<.001) in Chapter 7.

- Stair width in terms of need for rest that agrees with recommendations of Pauls, Fruin and Zupan (2007).

Objective O-2

Explore the impact of the intrinsic factors associated with an individual's performance in terms of the ones that are significant.

Fatigue is shown in Factor Analysis in Chapter 7 as having a cut-off value in the major principal component[226] >0.9 (p<.001). Its correlational relationship with the other functional limitations is highly significant across all the buildings (R>0.3 and p<.001). It is potentially synonymous with the global perceptual distance impact measure of "too many flights" which can also be generalised across all the buildings which shows a causal relationship with estimated descent capability for 79.2% of all cases. The level of significance is only moderate but triangulation with actual distance descended and other intrinsic conditions should result in a higher level.

Obesity and level of fitness[227] also show a correlational relationship with estimated descent capability of R=0.56 for M1-M4 and 0.35 both of which were only moderately significant (p<.05).

Fear of crowds and fear of falling also show a correlational relationship with the number of health conditions which is highly significant (p<.001).

The individual health conditions that correlate at a high level of significance[228] and can be generalised are:

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[225] i.e. Fuller Figure and Mature Age Focus Group

[226] Eigenvalue of 7.8

[227] Level of fitness- M1-M4 computed variable comprising obesity linked with number of health conditions e.g. Hypertension, Type 2 Diabetes. M5-M6 via IPAQ measure.

[228] R>0.25 and p<.001 across M1-M6

- Sore knees and lower legs with postural stability ($p<.001$)
- Postural stability and fatigue ($p<.001$)
- Out of breath and fatigue ($p<.001$)
- Chest discomfort and fatigue ($p<.001$)
- Estimated distance traversed correlates significantly with pain in the lower limbs, fatigue and breathlessness ($p<.001$)

The above reflects the findings of Bergland et al (2008) except that these findings are from a "real world" study. A causal relationship was established between falls history (reported falls) and the above that was moderately significant ($p<.05$) and $R^2 = 0.3$ to support the grouping of the individual health conditions into a single variable.

Reduced vision and depth perception was not shown to be significant but did contribute to a fall in M2 as well as being strongly supported by the Fuller Figure and Mature Age Focus Groups.

All of these factors affect an individual's confidence and ability to safely use the stairs without placing some pressure on the other members of the Group and establishes the need for increased inclusive participation in evacuation planning, training and practice.

Objective O-3

Establish the extent to which groups are formed, the location of this formation, the structure and likely size, expected behaviour in terms of assistance available, possible risk associated with this assistance and the individual member's estimated threats. This extent is to include any outlier incidents of falling or situations where an individual cannot proceed any further down the stairs

The rate of group formation is a valid measure within itself because the pattern (Hak and Dul, 2009) was consistent across all the buildings where the rate of group formation can generalised as being greater than 30%. This differs from other studies such as Boyce at al (2011) which set the rate at approximately 14%. The rate of group formation is also confirmed longitudinally from the Exploratory case study. The focus group comments from the Explanatory study do provide further support in terms of group dynamics as follows:

- Estimated pressure from group members on those members of the group who could not go down the stairs at the same speed to do so thereby increasing the risk of falling due to dizziness or fatigue.
- Pressure on Group members to physically look after those members who fell or were unable to negotiate the stairs because of lack of fitness or other health condition.

There is a pattern in the frequency of group formation in terms of where the relationships were formed (>60% on the floor) and where they met (>30% at the entry to the stairs). The mean taken across M1-M6 and 3 and 7 is 60% met at the stair and 60% formed the relationships in their workplace. The degree of group formation may be defined by the layout of the working areas or more likely the management strategy as confirmed in the two Content Analysis Studies in Chapter 6.

There are no significant findings from the survey but observation of video files indicated a range of group sizes from 3 – 6. This is also based on feedback from the observers. No other information is available as to structure (see triangulation schedules in Appendix A7-6).

The content analysis studies confirm the findings of Fahy and Proulx (2005) in terms of the predominance of altruistic behaviour as shown in Chapter 6. There was, however, some indication of the opposite especially involving the intolerance of delays caused by slow movers. This attitude, although not dominant was also partly reflected in the WTC 9/11 incident analysis and in other sociology research[229].

The dominance of altruistic behaviour can result in members of following groups offering assistance in event of a fall or similar in the primary group. They may not be trained to do so as was the group who assisted a mobility impaired woman to evacuate in an evacuation chair[230]. An author based study outlined in Chapter 6 extending the work of Adams and Galea (2010) showed the following re the number of people required to assist morbidly obese individuals. This could require more individuals than those who were group members. The descent speed could slow to 0.2m/s causing severe delays for following groups. The stairs would not have been wide enough for people to pass. Solutions where a group is trained to assist can overcome this problem. The author showed that an individual using an appropriate device and expert assistance could safely ascend a stair with a 38.5^0 at an adjusted speed of 0.5m/s which would not have created any real problems in the M1-M6 evacuations[231].

There is also a significant finding from the Fuller Figure and Mature Age Focus Groups re the risk to others posed by those who are unfamiliar with the stairs and with procedures. There was a reasonably significant correlational relationship between warden instructions and the use of a designated stair ($R=0.3$ and $p<.01$) for M1-M6 so that the focus group comments can be generalised.

A further risk posed by groups is:

- Obstruction of view of steps

[229] Puhl and Brownell (2001) and Puhl and Latner (2009)

[230] Determined from WTC 9/11 Content Analysis and Zmud (2007)

[231] See Chapter 7 Triangulation Tables

- Interference with the individual's focus due to the level of communication within the group or using mobile phones[232]

Descent speed analysis of groups show that in many instances individuals may be obliged to descend at an uncomfortable speed as reported in Chapter 7 which increases their risk of falling. This is also confirmed by the Fuller Figure and Mature Age Focus Groups in Chapter 6.

Objective O-4

Establish whether or not the performance of office workers in descending multiple flights of stairs can be measured as a function of a maximum number of storeys that can safely descend without a rest in the context of the relevant extrinsic and intrinsic factors. This level of measured performance is seen as their functional ability.

An inclusively based measure of estimated descent ability has been created that provides a highly significant causal relationship between the accumulated percentage of a population and their estimated descent capability. This was developed using a combination of pattern matching and comparison of means results. It is highly significant for the relationship:

Y (accumulated percentage population) = $-0.017x^2+2.7449x - 3.7391$ (where x is the number of storeys the individual can cope with.

The adjusted R^2 is 0.9 with $p<.001$. This relationship has also been justified in the longitudinal study between the Exploratory Case Study and the 2008-2010 Case Study in that **≤ 50% population estimate that they can descend a maximum of 20 storeys without a rest.**

An occupant's mean estimated descent capability is shown as a direct function of their actual descent ability ("too many flights"/ floor of origin) where

[232] Supported also by an experimental study concerning use of cellular phones by Kuzel et al (2008) and a real world case study of group communication on outdoor steps by MacLennan et al (2011a).

the R^2=.792 and p<.05. When the comment too many flights correlates highly with floor of origin (p<.001) and also with all the health conditions that have been reduced to a single variable in Chapter 7 factor analysis at the same level then this objective is satisfied. These also correlate at the same level with "descent risk" and "visibility and support" for 100% of the buildings in the correlation matrix in Table 7-8 and 7-9. When this is further explained by the comments of the focus groups on the impact of 'spiralling action and distance", fear of falling and the fear of crowds, then the impact of distance on performance is even more significant.

Figure 8.1 is the example of a simplified RCA[233] that could be used in conjunction with the development of an inclusively based personal emergency evacuation plan that explored the safe use of the stairs or other system that could involve the following on a joint basis:

- Determine all the intrinsic characteristics via a survey instrument similar to that used for the focus groups.
- Conduct a stair descent test to establish a comfortable descent speed and also to provide additional information to finish the survey. If a stair descent test cannot be used then a walking test as used for the Fuller Figure and Mature Age Focus Groups and convert the walking speed to a descent speed using Riener et al (2002) and Fujiyama and Tyler (2010).
- Assess the stairs and establish level of descent risk using Chapter 7 data together with the level of ventilation and illumination that steps are clearly visible and so as not exacerbate the onset of dyspnoea.
- Assess stair descent capability via level of fitness from IPAQ (short form) combined with number of self designated functional limitations. Jointly determine the percentile of population within the intrinsic characteristics would fit and from there the individual's estimated descent capability.

[233] RCA is Root Cause Analysis

- The individual should therefore determine their fall risk compared with the level on which they will work and the amount of rest spots available.

This RCA tool can be used following the same principles as outlined by Matheson (2003) where an occupant and the OH&S team jointly evaluate the occupant's functional capacity for the various occupational tasks of which trial evacuation is one.

The section of 7.7 in Chapter 7 also highlights the increased risk of falling that was determined via triangulation of the focus group descent speeds with those observed on the stairs in buildings M1-M6 using the impact of "hurrying" caused by a group dynamic and the increased risk of falling. This also underpins the importance of fatigue as follows:

Triangulation therefore confirms that fatigue relates directly to distance (estimated and measured) and is the most critical intrinsic factor underpinning an occupant's estimate of their descent capability. Chapter 7 shows elsewhere that falling risk is also linked indirectly with fatigue so that it also underpins estimated descent capability.

8.4.3 Additional "Spinal" or Causational Findings

Stair Comfort is synonymous with descent risk. As stated in the previous section stair comfort is synonymous with descent risk and confidence. This is further supported by the following:

- Principal component 2 of the factor analysis as shown in Chapter 7 show that visibility is significant referring and that the handrail "supports" the finding of the steps which includes legibility and foot placement. The cut off values are > 0.9. There are only two principal components and these cover 83 percent of the variance.
- Visibility and support would have been a similar principal component if the Exploratory Case Study data could have been linked to each respondent. Chapter 7 shows that the pattern has been consistent over the last 30 years.

The causational relationship is small but highly significant ($p<.001$) and as before is based on data aggregation being R=.59 (M1-M4) and R=.285 (M5-M6). The significance of the relationship increases being supported by triangulation with the measured data. The Focus Group comments also support it.

The percentage of population classified as obese with more than two health conditions that were at risk of falling were triangulated with observed descent speeds and subjected to a regression analysis. The resultants R^2 all exceeded 0.2 and were moderately significant. This improved as originally described with the aggregation of the data so that there was a pattern across M1-M6. The percentages of the population at risk were very small varying from 2-8%. Finally obesity as measure of fitness is as follows:

- NZ varying from 3.4% to 7.4%.
- UK at 14.7%.
- UAE at 15.65%.
- Australia at 9.9%.

8.4.4 Highly significant correlational relationships

The Individual

The "Individual" core consistency filtering schedule in Chapter 7shows a highly significant relationship between fatigue and the variable "too many flights" across 100% of all the buildings. This shows up a reliable internal construct especially when "too many flights" has a causal relationship with actual distance descended[234] that is reasonably significant. Fatigue also correlated at a high level of significance with the number of functional limitations. The latter included arthritis, other lower limb pain, asthma, and chest discomfort.

[234] Form of triangulation where the respondent nominated the level on which they entered the stairs which was then converted into an actual distance in metres.

There were two factors that were not shown to be highly significant via quantitative analysis but are seen to be highly significant from actual real world testing. The first factor is loss in stair descent confidence and speed due to inappropriate footwear. This is based on observations of one of the members of the Sydney BMI Benchmark Focus Group during a 32 storey descent test. The person was fit[235] although she did suffer from asthma to a certain degree. Evidence gathered from her sound-file[236]. The other is seen as being the impact on stair confidence by the variable, "ratio of tread width to shoe length". When the entire 2008-2010 case study data set is aggregated there is a highly significant and yet weak correlational relationship between the two. This is confirmed in the Exploratory Case Study (Chapter 5) by pattern matching between the two. Members of the Fuller Figure and Mature Age Focus Groups confirmed the Exploratory Case Study finding. It is the author's opinion that this factor is still significant even if it is based on an aggregated data set because of the support for longitudinal generalisation between the Exploratory Case Study output and the Focus Group comments. Wright and Roys (2008) further support this finding in relating tread width to falling. An additional analysis shows that there is a moderately causal relationship between the constructed "risk of falling" and the ratio of tread width to shoe length[237].

Other highly significant causational relationships for the Individual are described in previous sections.

The Group

The rate of group formation cannot be shown to be highly significant from the survey responses from the Exploratory and 2008-2010 Case Studies

[235] According to the IPAQ measure (Sjostrom et al, 2005)

[236] Electronic file from cassette tape recording

[237] Risk of falling extrapolated from Johnston and Pauls (2011) and regressed against ratio of foot length to tread width for the aggregated 2008-2010 dataset.

following similar patterns. Conservatively > 30% of all cases showed that groups were formed prior to entering the stairs. This finding can be generalised across all buildings regardless of evacuation strategy[238]. The frequency was also confirmed for M1-M6 from analysis of video data in Chapter 7.

Descent speeds were analysed in Chapter 7 against those respondents who reported that they were obese and had a number of health conditions. The percentage who were obese and had more than two health conditions was extremely small (<6%) and speeds for many of these respondents exceeded those of the tests carried out members of the Fuller Figure and Mature Age Focus Groups,

The impact of group dynamics cannot be shown from the quantitative analysis of the survey in the 2008-2010 Case Study. The Fuller Figure and Mature Age Focus Groups clearly illustrate the extent of group dynamics supported by the outcome of the NY Times Blog Content Analysis where group members who were unfit and had a number of functional limitations (e.g. arthritis and hypertension) had an increased fear of falling when under pressure to move at the speed of the group. This pressure was not exerted by the group but was because the individual concerned was too embarrassed. Fear of falling and fear of crowds has a highly significant (p<.001) relationship with the number of health conditions which was the situation with the Focus Group members who provided the opinion. The author refers to the work of Mademli et al (2008) as the triangulation schedules in Chapter 7 and Appendix A7.6 show no significant correlations between descent speed and fear of falling. There is however a distinct relationship showing up from the Fuller Figure and Mature Age Focus Group walking tests. The resultant speeds are some 24% less than 0.5m/s exemplified by the comparison of BMI Bench Mark Focus Group results with other similar studies in Chapter 6. This therefore increases the risk of falling

[238] Chapter 7 shows the overall analysis but Appendix A7.6 may also be consulted for more detail.

because of the triangulation between their reported opinion and their measured descent speeds[239]. Where other descent speeds fall within the range recorded by the Focus Groups there is a distinct pattern shown on the descent charts and survey responses that the overall descent is slower due to delays, the width of the stairs or the density. This is supported indirectly by Galea et al (2008) where density masks fatigue and hence decreases the risk of falling because of the slower descent speed. The author also argues that the study carried out by Shields et al (2009) shows that the accounts of the descent ability of a number of individuals with self designated functional limitations may be influenced by density or their "comfortable" descent speed experience coupled with the number of rests they may have taken. M5 shows a reduced rate of fatigue due to the increased estimated and actual density. The reduced rate also pattern matches with the mean level of fitness in the building as compared with M6.

There is a highly significant correlation between the fear of crowds and falling which support an additional Focus Group comment concerning the obstruction of an individual's view of each step. This related especially those members who had reduced vision and/or depth perception.

The Stairs

This has already been discussed.

Management and Maintenance

There are highly significant relationships between the evacuation strategy and the resultant descent speeds that are shown via triangulation in Chapter 7. The author is of the opinion that uncontrolled (one out – all out) strategy is safer for all than

[239] See also Madelmi et al (2008).

the sequential strategy because of the apparent reduction in travel speeds due to increased delays, width of stairs and delays[240].

8.4.5 Reasonably significant correlational relationships

The Individual

The following correlational relationships are reasonably significant ($p<.01$) across most of the buildings (M1-M6):

- BMI and pain in lower limbs
- Reduced vision and fear of falling from Focus Group comments.
- Number of health conditions and too many flights
- Level of fitness and fear of crowds[241]
- Mets (BMI/No. health conditions) with dizziness, pain in lower limbs and dyspnoea.
- The percentage occurrence of health conditions follows a distinct pattern across all M1-M6 buildings so that a generalisation can be made that 19.6% of the occupants will have one or more health condition and that a minimum of 11.7% are obese.

The Group

Groups following warden's instructions and using the designated stairs correlated with a reasonable level of significance. When this finding is combined with the outcome of the WTC9/11 Incident Content Analysis the finding could be extended to include the level of influence of management over group formation. This needs to be tempered with the consensus reached by the Focus Groups in Chapter 6 and a parallel study carried out by MacLennan et al (2011a) where lack of group focus on the descent task produced by such activities as

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[240] As a result of pattern matching between stair descent chart information, triangulation schedules of travel speeds with those occupants who were and were not at risk of falling

[241] Fear of crowds also correlates at a highly significant level with fear of falling

talking on a mobile phone[242] or unrelated communication between members can annoy other groups as well as slowing the rate of descent. Group knowledge i.e. knowing what to do is also shown to be significant through pattern matching across M1-M6 in the 2008 -2010 Case Study.

Perception of group members of the number of others in the stairs and the impact on descent speed shows a correlational relationship that is reasonably significant because of its pattern of triangulation with density measurements shown in Chapter 7 and Appendix A7.6.

The Stairs

The height of a building does have a reasonable impact on the distribution of entry levels and therefore the mean distance descended in Buildings 3, 7 and M1-M6 as it forms a pattern related directly to the height as a function of the distribution of the occupants.

The impact of actual descent distance has a reasonably significant causal relationship with the too many flights. This in turn relates reasonably significantly with fatigue.

There is a reasonably significant pattern of frequencies for handrail use supported via triangulation and also Focus Group comments that show an increase in confidence with holding on to the handrails[243]

Management and Maintenance

Cleanliness was found to be highly significant in the Exploratory Case Study but was only commented on by the Focus Groups to a minor extent in the 2008-2010 Case Study. It would appear that a longitudinal generalisation could

[242] Kuzel et al, (2008)

[243] Also supported by Reeves et al (2008a)

be made that the relationship would be reasonably significant as at the date of this Thesis.

Cleanliness also relates to no obstructions being present, smooth handrails and clean and non-slip surfaces. General maintenance also follows the same trend so that cleanliness is described as being maintenance of the stairs themselves in as good a condition as when they were constructed.

8.4.6 Moderately significant and other qualitative relationships

The Individual

It is interesting to note that there is only as very weak and moderately significant relationship ($p<.05$) between the number of falls experienced by an individual and their fear of falling. It is more likely that a person with an anxiety condition who has experienced a fall would simultaneously return a common response between the two. There is a moderately significant relationship between obesity and fear of falling based on aggregated data.

The author challenges this relationship based on the following:

- The characteristics of the two individuals who fell during the trial evacuation in M2.
- The author's case study during the Christchurch Earthquake where a combination of fear of falling and pain in the lower limbs caused him to slow his rate of descent thereby holding up all the others behind him and "clutching" on to the handrails. See also "Stairs" in this section concerning a dichotomous requirement.

Other findings considered to be moderately significant are:

- Observations gathered from the descent chart schedules show that there were cases in every one of the buildings except M1 of overtaking and apparent aggressive behaviour. The person being overtaken was most likely a slow mover due to inappropriate footwear (e.g. scandals, high heels and “flip-flops”) or functional limitations/ fatigue.

- The extent of overtaking in M2-M6 suggests that wider stairs would be appropriate and that rate of overtaking would have increased. This can be supported by the range of descent speeds in Table 6-20 of between 0.6m/s and 1.2m/s which translates into 4 storeys per minute to 8 storeys per minute. From an anthropometric analysis based on “uniscan” data carried out by MacLennan et al (2008) and further corroborated by Montgomery and He (2011) stair widths should be increased above the current minimum of 1000mm to 1500mm to facilitate overtaking and resting.
- A small percentage of slow movers (>2%) held up people behind although this did not register significantly in survey responses.
- Examples in M5 and M6 of Individuals resting although stairs were only 1000mm wide. Once again wider stairs would provide space on the intermediate and main landings for resting.
- BMI and balance for 50% of the buildings improving to reasonably significant when the data is aggregated. There is still sufficient support in the literature[244] and from the Fuller Figure and the Mature Age Focus Groups for this relationship to be reasonably significant.

Group

Group formation has only been shown to be significant by pattern matching across frequencies of M1-M6 and longitudinal comparison with Buildings 3 and 7 from the Exploratory Case Study. Altruistic behaviour featured in the 1980’s[245] but this appears to have changed slightly over the last three decades as evidenced in the NY Times Blog[246] Content Analysis in Chapter 6

[244] Corbeil et al (2001)

[245] Chapter 5

[246] Parker-Pope (2007)

where 18% of the Group Core Consistency dealt with "aggressive" behaviour. The extent of overtaking is significant as previously mentioned so that Group permeability[247] may have changed. Primary Groups may now be prepared to let others from affiliative groups penetrate their boundaries. "Aggressive" behaviour need not be taken all as negative. The Content Analysis of the WTC9/11 survivor accounts (Dwyer and Flynn, 2004) shows the example[248] of an "over-taker" stopping to help an obese woman in pain descend the stairs until clear of the building. There are a few instances of this in the M3-M6 trial evacuations.

Group cohesion is still the most significant as exemplified by the evidence of altruistic behaviour in the Content Analysis Studies in Chapter 6, the rate of group formation and the literature[249].

The Stairs

The Focus Groups in Chapter 6 mentioned the problem associated with the width of the stairs for the purposes of overtaking and resting. Observation of the stair descent chart schedules in Chapter 7 and Appendix A7.6 shows the extent of overtaking being common to all buildings supports this. The stairs at present are only 1000mm in clear width between handrails. Anthropometric analysis carried out by the author[250] in association with the 2008-2010 Case Study show that overtaking would be possible with stairs with clear widths of between 1200 – 1500mm. These widths would require two handrails which is now the predominant requirement in most countries. There is a dichotomy of requirements here which was raised by the author in an international workshop on stair safety (MacLennan and Ormerod, 2011). The Christchurch Earthquake Case Study involving the author's evacuation of an office building on February

[247] Knowles et al (1976)

[248] Chapter 6

[249] Fahy and Proulx (2005)

[250] MacLennan et al (2008)

22nd 2011 at 12.51pm shows that if the stairs in this instance had been 1500mm wide then access to the second handrail would have been difficult. The author's descent speed would have slowed significantly and his risk of falling increased as well.

Management and Maintenance

The only remaining finding of that is moderately significant in terms of the strength of the relationship is one associated with risk management. The risk of falling has been determined as a percentage of the occupants in buildings M1-M6 as follows:

- M1 – 6% at risk.
- M2 – 13% at risk.
- M3 – 14.7% at risk.
- M4 – 3.4% at risk.
- M5 – 7.4% at risk.
- M6 – 9.9% at risk.

These percentages were determined as described in Chapter 7 as explained by the causational links shown in Figure 8-1 and show a causal relationship[251] with distance of $R^2=0.52$ and is moderately significant ($p<.05$). The surfaces of all the stairs involved is hard or lacks the ability to absorb impact energy. The risk of associated injury is quite high although the percentage of population at risk of falling is quite small.

The risk management policy could concentrate on the seriousness of the outcome rather than the likelihood of occurrence. The importance of OH&S legislative requirements is summarised in Chapter 2 and shows that a preventative approach is one to follow given the contribution of the extrinsic

[251] Equation of *y (percentage of population at risk) = 0.3039x +2.1276 where x = no of storeys*

factors to falls. Management for the greatest cost effective return should therefore be committed to:

- Minimisation of descent risk and the provision of visibility and supportive conditions associated with the stairs.
- Provision of a clean and well maintained environment.
- An uncontrolled evacuation strategy so as to control descent speed.
- Knowledge of the stairs as well as procedure via a sound training and practice programme.

The above requirement and recommendation for management is more than reasonably significant and is especially important given that ≤ 50% of the population have an estimated descent capability of ≤ 20 storeys.

8.4.7 STAIR – Design Parameters from Focus Group Consensus

As a result of the Focus Group suggestions, triangulation in Section 7.6 and Table 7-13 the modifications suggested are:

<u>Stair comfort to create confidence or decrease descent risk</u>

- 300mm goings corroborated by the mean shoe sizes determined of between 280-300mm and their association with occupant concern in the survey.
- Stair pitch being in the preferred zone of between $23^0 – 32^0$
- Uniformity with construction tolerances as specified of 5mm maximum.
- If some variance is to be accepted then two handrails should be provided within reach as evidenced by the need in Appendix A7.5.
- Number of turns kept to a maximum of two per level. The well void should be such as to avoid the user being distracted by views of lower levels.

- Stairwell should be properly maintained by management so as to be free from obstructions, irregularities and surfaces that have a PTV less than 36.
- Levels should be clearly marked and doors provided with viewing ports.
- Nosings should not promote injury.
- Nosings should be clearly marked in contrasting colour (contrast sensitivity >0.3)

(Ref. also Roys, 2006; Alderson et al, 2010; Templer, 1992; Pauls et al, 2007)

<u>Visibility and support:</u>

- Resting space every five floors as detailed in Chapter 6 or provide wider stair between 1200-1500mm between walls which would not only cater for counterflow and overtaking but would also provide resting space. This requirement is also confirmed by the number instances of overtaking in M5 and M6 that alleviated frustrations of some with slow movers. Additional space would address needs of occupants who became anxious during descent because of a fast descent speed. (Ref. Pauls et al, 2007 and MacLennan 2011).
- Handrails should be continually graspable (32-45mm diameter) and be of a contrasting colour.
- Vertical and horizontal surfaces should contrast in colour so as to increase the legibility of the steps.
- Doors should be recessed and sighted so that flows are not diametrically opposed; this allows for smoother merging.

- Illumination should clearly define the steps for each full flight without creating glare or shadows. This aspect must be maintained as made very clear in the Exploratory Case Study.

- Conditions must be adequate so as to avoid heat building up and lack of air. Mechanical ventilation is vital and must be maintained especially to operate in evacuation mode (M2 survey results and observations confirm this especially with the evidence of two falls).

8.4.8 Other than stairs?

Kinsey and Galea (2010) show how people will respond to the use of lifts. The author conducted a similar lift survey as part of the Exploratory Case Study and 2008-2010 Case Study on Buildings M1 and M6. The author also conducted another case study using an evacuation chair rated for 200Kg. The only correlational relationship in the M1 and M6 Lift survey showed that waiting time was moderately significant with anticipation of smoke spreading into the lobby.

It is interesting to note that with the results from the NY Times Blog Content Analysis in Chapter 6 concerning aggressive or “impatient” group behaviour supported by overtaking behaviour observed on the M3-M6 Stair Descent Charts in Chapter 7 and Appendix A7. The latter show that occupants could quite well decide to use the stairs when the protected lift lobby becomes too crowded or the waiting time too long. This is exactly the same response recorded by Kinsey and Galea (2010)[252]. The findings from the author’s evacuation chair study which according to the WTC9/11 Content Analysis in Chapter 6 and Zmud (2007) is inclusive show that a group with adequate training can achieve a safe descent speed of 0.5m/s which would have compared favourably with a similar study carried by Adams and Galea (2011) and those speeds in M1-M6 described in Chapter 7..

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[252] See also Appendix A8 for further details.

In addition to the evacuation chair study the author conducted a further simulation study[253] where he showed that up to 30% of an office population in 2030 may not be able to safely negotiate stairs that were less than 1000mm wide and had no resting areas on the landings. This 30% were diverted to safe evacuation lifts where the waiting time was minimal and the remainder of the population used the stairs (uncontrolled evacuation). A mean descent speed of 0.6m/s was achieved, the risk of falling mitigated and the overall duration of the evacuation shortened.

8.5 Contribution to the Body of Knowledge

The "knowledge gap" was identified in Chapters 1 and 2. This gap has been filled by the delivery of the PhD Case Study aim and Objective O4[254]. Otherwise there needs to be clear "evidence" that a contribution has been made. A contribution to knowledge can comprise:

- ***Models*** *– framework for reviewing the literature and collecting and analysing data.*
- ***Research methodology*** *– e.g. creative use of existing analytical tools for triangulation.*
- ***Establishing new FACTS*** *within a context hitherto not "explained" in the literature.*

The use of a "model" (framework) based on RCA (Portwood and Riesing, 2007) to interrogate a vast field of stair descent research, establish the context of descent performance in association with Delphi, Directed Content Analysis and Focus Group techniques and then to use the same results to gather and analyse the performance in practice i.e. trial evacuations is an innovative and original contribution to knowledge. Factor analysis was used to reduce data on Stairs

[253] MacLennan et al (2008) in a case study on assisted evacuation carried out using the ELEVATE model where elevators were designed to evacuate 30% of the building population. The case study was presented at an international elevator conference in Thessaloniki in Greece in 2008.

[254] **Illustrated in Section 8.4 via the satisfaction of the Aim and Objectives of the PhD Case Study.**

gathered from survey respondents and measured in the buildings the respondents evacuated. The Principal Components of "Descent Risk and Visibility and Support" were found to be similar as shown in Chapter 7. This is an example of a contribution to knowledge in triangulation (research methodology). The main examples of FACT from section 8.4 are that increased distance traversed, group members obstructing others' view of stairs and hurrying can increase the risk of falling[255] . Further examples of FACT are the determination of the decrease in descent capability over the last 30 years via longitudinal case study and the demonstration of the impact of density on fatigue (explaining studies of Galea et al, 2011 and Pauls, Fruin and Zupan, 2007).

8.6 Study Limitations

8.6.1 Scope of Study

The scope and size of this study is similar to that of Peacock et al (2009) but the backing resources were not. Radio frequency identification systems could have been used to locate occupants on the stairs and their associated time of descent at strategic levels. The associated price would have been some £25,000 as compared with the cost of 34 miniature video cameras with time stamp, extra time manually abstracting times and other extras amounting to some £12,300. The accuracy of the descent times could be challenged as could the distances traversed but the author had used video cameras in his 1980 research project analysed in the Exploratory Case Study. It is still necessary to treat the camera solutions as a limitation but it has distinct advantages especially in terms of recording human behaviour. Observers with Dictaphones were triangulated with camera images and times as described in Chapter 4 to increase reliability.

The video equipment system was far too labour intensive to install and the impact of adverse conditions such as was the case with M2 was not

[255] Confirmed via triangulation between explanatory and trial evacuation studies.

anticipated. Observer resources were scarce outside Australasia and extra training was required. The extent of observations on M2 and M3 were affected.

The constraints imposed by the building owners/ managers reduced the response rate in some instances to 10% and affected the distribution of respondents within some of the buildings[256]. Many of the building managers were extremely sensitive about their strategies and systems so that the author was restricted in gathering data for the Management and Maintenance core consistency.

The range in building height did not resemble the sample that was analysed in the Exploratory Case Study as the highest in the 2008-2010 Case Study was only 36 storeys as compared with 45 storeys. Examples were not available from the United States through contacts made in San Francisco due to the risk-averse stance of many of the office building owners. Success here may have resulted in the availability of buildings of increased height.

The M2 systems failed on the day of the evacuation so that many of tenants were unable or refused to take part. This affected 30% of the observers who were unable to access the stairs. Triangulation data from this building was compromised due to the lost video data. The Owner did not agree to a repeat of the exercise and the author failed to secure any additional sites. Observer sound files were available and overall times were available. 80% of the observers still descended.

The overall scope of the PhD Study using the Case Study method[257] involving the inclusion of focus groups and the content analysis of sources not analysed in the literature before added a breadth to the PhD Study so that a decision could have been made to reduce the number of buildings in the 2008-2010 Case Study and applying more effort in increasing the number of responses.

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[256] Details of the distribution of the survey respondents in M1-M6 may be found in Appendix A7.6

[257] Yin (2009)

8.6.2 Methodology

Case study methodology was selected as justified in Chapter 3. A process was set up so that changes could be made during the Delphi Group consensus sessions and the conduct of the trial evacuations and focus groups. The survey instruments therefore evolved using a PDSA[258] process step. Although this type of research design is considered to have its advantages[259] it resulted in data coding problems to make the data from each cycle comparable. It also affected the length of the questionnaire for M5 and M6 when it was expanded to include the Short Form IPAQ[260]. The rate of response was also affected.

The methodology itself resulted in more detailed analysis than that required for other methods seeing a feature of Case Study or Pluralist research methods is triangulation. Each building was required to be analysed separately to establish whether or not patterns could be established. Establishing causal and correlational relationships that were significant changed with the extent of data aggregation which is seen as compromising generalisation. The latter is seen as being an advantage when compared to findings derived elsewhere in the evacuation literature. The limitation was addressed in part by aggregation according to the fitness evaluation tools used.

The relationships most affected by aggregation were fatigue/ fitness / descent risk and estimated descent ability. These differences are highlighted in Chapter 7. The author believes that the further analysis of the highly significant relationships between "too many flights", fatigue and the health condition was an adequate control for the variable "too many flights" when regressing it against the distance actually traversed (R^2=0.79 and $p<.05$).

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258 Plan-Do-Study-Act Cycle (Institute for Innovation and Planning, 2011)

259 Flyvbjerg (2006).

260 International Physical Activity Questionnaire (Sjostrom et al, 2005)

8.6.3 Construct Reliability

Many of the causal relationships established from the 2008-2010 Case Study are weak and in certain instances only moderately significant. They were further investigated through triangulation analysis and explained. Focus group consensus was also used with results being filtered prior to triangulation[261]. Longitudinal checking with Buildings 3 and 7 from the Exploratory Case Study was also carried out. Factor Analysis outcomes also improved the quality of triangulation[262].

8.6.4 Representative sampling

The makeup of the samples from each of the 2008-2010 Case Study Buildings may have been compromised by the low response rate. The distribution of responses was therefore tested for each building using the weighted mean evacuation level. Using pattern matching[263] the distribution followed the same pattern as the building height so that those variables relating to distance were based on representative data.

The impact of the low response rate on the sample makeup may have contributed to the methodological dichotomy highlighted in Chapter 7 concerning the aggregation of data. Aggregating M1-M4 into one dataset and M5-M6 into the other is based on sample size and also survey instrument type.

8.6.5 Assumed outcomes?

It could be argued that the procedure used to establish the risk of falling in Chapter 7.6 and Appendix A7.6 for each building is based on an assumed

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[261] See Chapter 7.

[262] Measured and Survey datasets for stairs was reduced to two principal components for each. The resultant variables of descent risk and visibility/support corresponded which is a significant finding in itself. See Chapter 7.

[263] Hak and Dul (2009).

relationship[264] of the impact of an "uncomfortable" descent speed. There is a converse conclusion which is that occupants who were obese with two other functional limitations had no problems with the "uncomfortable" descent speed and this could have caused some of the weak and moderately significant causal relationships with estimated descent capability. The author's basis for the risk measure is assembled from:

- Galea et al (2008) and Spearpoint and MacLennan (2012) conclude that density (including delays caused by merging and the width of stairs that discourages overtaking) may mask fatigue due to decreases in speed and increased stoppages allowing for people to rest.
- The parallel Focus Group Studies where the BMI Benchmark Group descent speeds were well in excess of the Fuller Figure and Mature Age Focus Group speeds. This matched the studies summarised by Spearpoint and MacLennan (2012) where walking speed can be directly linked to functional limitations.
- Fuller Figure and Mature Age Focus Group consensus concerning the increase in their fear of falling when they felt obliged to keep up with the group.
- Mademli et al (2008) and Kang and Dingwell (2008) mention how increased walking speed associated with other conditions can increase the risk of falling.
- The degree of significance in the causal relationship between the responses of "too many flights" from the survey with the distance actually descended.

8.6.6 Methods of Analysis

Only bivariate regression analysis appears to have employed in the attempt to establish causal relationships between variables. This is not the case as

[264] Shields et al (2009) where they showed that the amount of self designated functional limitations an occupant possessed had no impact on their estimated descent capability.

multiple or multivariate logistic analysis was employed but found to be inappropriate in many cases because of the mix of data types. Bivariate regression and linear and logistic regression was found to be more suitable based on the Ishikawa Chart Model of Root Cause Analysis. This was also supported by the triangulation process described in Chapter 4 and applied in Chapters 5-7.

8.6.7 Interpretation

Interpretation based on quantitative analysis would show that the aim had only been partly satisfied because of the strength and significance of the relationship. The challenge for the overall PhD Study was that it was a real world study and not experimentally based. The study was associated with the "Built Environment" where findings could vary for any amount of reasons from building to building. Amaratunga et al (2002) suggest that a mixed method approach would be more suitable. This was similar to the case study approach justified in Chapter 3 where the interpretation needs to be based on a holistic analysis and where the "unit of analysis" is clearly known. A main feature of the case study or mixed method of analysis is triangulation because;

"Triangulation has proved to be an effective tool for reviewing and corroborating findings in the survey, assessments and appraisals….."

(pp.13, Hales, D., (2010) *An Introduction to Triangulation,* UNAIDS Monitoring and Evaluation Series.)

Triangulation establishes a pattern between self reported and observed or measured data. All patterns established this way can be used to further explain and support the quantitative outcome and in certain instances where the finding can be generalised across the building specific datasets the findings could be seen to be more important. This is a distinct advantage.

8.7 Further Research and the Future

8.7.1 Further Research

Case Study driven trial evacuation research should be replicated so that the generalisations can be further confirmed. A comparative review of studies utilising different methodologies should be carried out and the reliability of results compared. This study could be repeated combining the following:

- RFID and video technology so as to spatially locate occupants in the stairs and also identify their questionnaires. Also the associated automatic statistical analysis software
- The assembly of a group of stakeholders who would assist with the sourcing of participant buildings.
- The assembly of an increased number of focus groups with same structure as this study.

The development of a benchmark evacuation strategy and testing protocol using an action based research method and comparison with other trial evacuations from the overall study

8.7.2 The Future

The trends will most likely continue according to the Chicago based Council on Tall Buildings and Urban Habitat[265]so that there will be buildings up to a mile high (1600m) by 2025. Evacuation planning will be a challenge and yet this PhD Study shows that the procedure needs to be kept simple. Assisted evacuation will be by lifts (Bukowski, 2010). Kinsey et al (2010) have researched this aspect and have conceded that there will still be a need for stairs. Elevator driven evacuation will therefore be sequential and complex. Based on

[265] Tim Johnson in the Houston Chronicle, Tuesday 25th September 2012.

the findings of this PhD Study and taking into account the findings of Kinsey et al (2010) the stair use will therefore reflect lower densities and faster speeds. The risk of falling will also increase. The health and safety aspect of evacuation planning will increase the need for an inclusive approach to ensure worker commitment (Gwynne, 2008).

The RCA framework (Portwood and Reising, 2007) developed in this PhD Study has facilitated the classification of the context of individual descent capability on multi flight stairs along with the associated critical factors. These factors can be generalised (Yin, 2009) so that this framework can be used as structured planning tool[266] for assessing likely stair descent problems for employees with any combination of intrinsic characteristics as suggested in Section 8.4. It can also be used more globally as a design tool for use in enhancing the stairs and emergency systems with simple cost effective solutions e.g. sustainable refuge planning such as those noted in Chapter 7. Where the office building is similar to M6 the entire 2008-2010 method could be used with the only Explanatory Study being the use of specially selected focus groups drawn from the workers[267]. The time horizon would be annually with each year being a PDSA Cycle. This would promote continuous improvement of the evacuation plan and stair use in line with other health and safety practices[268].and is sustainable.

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[266] Similar to the framework and process developed by Matheson (2003).

[267] Similar to the PAR method used by Gershon et al (2007).

[268] Massey et al, (2007) *How Health and Safety makes good business sense*, Department of Labour, NZ.

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A STUDY OF THE PERFORMANCE OF OFFICE WORKERS DESCENDING MULTIPLE FLIGHTS OF STAIRS IN HIGH RISE OFFICE BUILDINGS IN TRIAL EVACUATIONS

VOLUME III

APPENDICES

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APPENDIX A3

RESEARCH METHODOLOGY

A 3.1 EXPLORATORY CASE STUDY REFERENCES

A3.1. Observation Instructions and Check List

1980 CASE STUDY - PROCEDURE FOR OBSERVING EVACUATION EXERCISES

Observer Name:

Evacuating from Floor:

Using the _________ stairway.

Number on Recorder:

A3.1.1 Preamble:
Because of the transitory nature of the events being observed and large size of a high rise office building and its population it is essential that the observers be a part of a well organised team. As a member of this team each one of you is being requested to record observations at some assigned position or sequence of positions in the building.

Your observations will be used to examine, in detail, to examine localised events at your assigned positions. Furthermore your observations, recorded on your portable tape recorders, will part of the re-construction of the whole evacuation exercise.

The following procedures relate primarily to the collection of data about the movement of people during the exercise. Please use your experience and judgement to conduct other observations which will assist in an objective evaluation of this particular exercise.

A3.1.2 Detailed Procedure:
(Note that a checklist permitting a rapid review of these procedures is provided at the end of this paper)

The immediate goal of your observations is to make a tape recording containing as much information as you can collect about the events and conditions around you.

Using a portable cassette tape recorder set to record continuously, you can need not be concerned with watching a clock and noting times for various events. As long as your recording includes some reference signal such as the evacuation alarm and at the end such as “final exit door” then it is a straightforward task to draw up a detailed log of your observations on a time scale. The log can be related to observations made by other observers at the same time. The analysis of your recording will be done for you leaving you with only the challenge of rapidly observing and reporting on the following conditions and events;

1. Occupant behaviour to the evacuation alarm signals.
2. The flow of occupants into your assigned stair.
3. Your own movement down the stairs with the occupants of your assigned floor noting each landing as you step on to it and also any delays or slowing down of the rate of descent.
4. The density of population in your immediate vicinity in the stairs and their distribution patterns (e.g. side by side. Single file etc.).

As you will note from this list, you are apparently requested to report on several things simultaneously. To make your observations challenging rather than impossible, the following detailed procedures are suggested:

(a) Prior to the exercise, record your name, assigned floor, and assigned exit on the recorder on side A of the cassette. Also check the number on the back of the cassette or write your assigned floor and exit number on the back if there is no number.

(b) Go up to your assigned floor about five minutes before the alarm is due to be sounded before the start of the exercise. Ideally you should wait with the main fire warden for your assigned floor until the drill starts. Before and during the drill, try to conduct your observations so that the activities of those around you are not interrupted.

(c) Prior to the alarm sounding record remembering that you are required to switch on the recorder five minutes before the start record the time on your watch as a starting reference time.

(d) Once your recorder has been switched on do not turn it off until you are outside the building.

(e) Move to the floor area next to your assigned exit. Make sure that the tape recorder is picking up all the background sounds and any comments you wish to make about how the people respond to the alarm.

(f) When your floor is due to be cleared take a count of the people as they go through the doorway into the assigned stair. In this case instead of counting “one. two, three etc.” a simple “Q” should be recorded every time a woman crosses and “P” for a male. This permits an accurate determination of the rate of flow into the exit and also assists in describing the gender mix of your floor.

(g) Try to be one of the last persons to leave your assigned floor by your assigned stair. Enter the stair as part of the last group so that you do not become separated from them. Also state approximately how many people will be behind you?

(h) As you down the stairs please record the floor number of every floor as you reach the landing. This is needed so that we can plot your progress down the stairs and estimate your descent speed.

(i) When going down the stairs, note at the lower floors, if people from these floors are entering the stairs before your group reaches them. Note any delay or congestion that this may be causing due to mixing.

(j) Note how people go down the stairs relative to each other e.g. side by side, single file, staggered formation a few steps apart etc. Try and keep yourself in the same pattern as the others with the same space in between.

(k) At each storey take a count of the number of people who occupy the area of one flight and one landing in front of you and record the number on the recorder e.g. seven in front. Follow this by the number using the handrail e.g. four on rail. This means that out of the seven people in front of you only four are using the handrail.

(l) Whenever your speed changes noticeably indicate this on the recording.

(m) When you arrive at the bottom of the stairwell you will see another observer handing out questionnaires. They will record the time that you pass and you should do the same. State your floor of origin loudly so that it will register on the other recorder as well. You are to take the questionnaire as it is handed to you and complete it as part of the survey.

(n) Also proceed to well outside the building before you turn the recorder off. Do not forget to record your final reference time before you do so.

OBSERVATION CHECK LIST

Observer: Floor: Exit: Recorder No.:

(Items marked with an asterisk are of high priority)

(a) * Record name, floor and exit on recorder before drill.

(b) * Meet with observation team in the ground floor lobby fifteen minutes before the start of the exercise and synchronise your watch with the rest of the team.

(c) * Go to your assigned floor five minutes before the drill is due to start.

(d) * Switch on your recorder when you reach the floor.

(e) * Record the time on your watch to the nearest second.

(f) * Leave your recorder running until you are well outside the building.

(g) * Note what happens in the vicinity of your exit.

(h) * Record a count of the people on your floor as they cross into the exit stair ("Q" for females and "P" for males).

(i) * Be one of the last to leave your floor but leave in the last "group".

(j) * Record each floor level as you step on to the landing at each level.

(k) * Note people entering the stairs as you descend.

(l) * Note how many people are in front of you on the flight and how many are holding the handrail.

(m) * Note how the people in front of you are spaced on the stairway.

(n) * Note any changes in your rate of descent.

(o) * Report to the observer at the bottom of the stairs.

(p)* Move well clear of the building and provide a reference time before turning off the recorder. Make any other observations that are relevant.

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A3.1.3 1980 QUESTIONNAIRE – DATA SOURCE AND CLASSIFICATION

Introduction

The data that was most suitable for use as an exploratory case study to determine:

(a) Whether or not it was feasible to continue a similar current case study in line with the Aim of the PhD Study as stated in Chapter 1 (Yin, 2009)
(b) The feasibility of using findings from the exploratory case study as the basis of a longitudinal link with the findings of the 2008-2010 Case Study

The data that was most suitable fitted within the classifications used to interrogate the literature in Chapter 2 as well as forming the context in which the performance of office workers going down multiple flights of stairs was to be studied. These classifications are also confirmed by the Delphi Group as presented in Chapter 6.

The original analysis was carried out using SPSS V2.1[1] and was archived on magnetic tapes. The latter were destroyed when the research was terminated. The only data that remained was in the form of hard copies of tables and project notes. This section shows the data source[2] and makeup for the exploratory case study.

Data classifications analysed in Chapter 3

Overall questionnaire design

The original questionnaire formed the basis of a survey of the total evacuation process and other emergency related issues. The questionnaire was a survey tool used to elicit and record the responses of office workers to a trial

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[1] Statistical Package for the Social Sciences Version 2.1

[2] Data source referred to here is the questionnaire.

evacuation in their place of work. Not all the questions forming part of the original questionnaire are therefore directly applicable.

The questionnaire was originally divided in to the following broad sections:

(a) Early stages of the evacuation (including level on which they commenced the evacuation)

(b) Movement to and down the stairs

(c) Reconstructed questions covering

- Physical characteristics
- Fire warden status, role and experience
- Organisational role and status
- Impact of going down the stairs
- Stair choice
- Group actions and experience
- Location at time of alarm
- Obstructions on stairs
- Functional limitations and difficulties with stair traversal
- **Estimated descent capability**
- Normal stair use – level of fitness

The questionnaire included in this Appendix has been highlighted in accordance with the data classifications referred to in Chapter 3 and analysed in Chapter 5. The classifications are shown in the following section.

Classifications of 1980 data for further analysis in the exploratory case study.

The classifications are as follows

- Extrinsic 1 - stair environment and location
- Extrinsic 2 – stairs
- Extrinsic 3 – handrails, lighting and maintenance
- Extrinsic 4 - density - others
- Extrinsic 5 - delays – others
- Extrinsic 6 - group formation
- Intrinsic 1 – confidence
- Intrinsic 2 – ability
- Intrinsic 3 – fatigue and distance

These classifications once analysed in Chapter 5 are regrouped into the classifications determined by the Delphi Group.

BUILDING EVACUATION QUESTIONNAIRE FROM 1980 STUDY RECONSTRUCTED TO SUIT PHD EXPLORATORY CASE STUDY

THIS QUESTIONNAIR HAS BEEN RECONSTRUCTED IN PART FROM AVAILABLE CODING SHEETS WHERE THE PARTICULAR DATA AND SECTIONS OF THE QUESTIONNAIRE ARE NO LONGER AVAILABLE

BUILDING EVACUATION QUESTIONNAIRE

THIS EVACUATION WAS ONE WITH A DIFFERENCE! It is being studied. Information on what you did can help to improve emergency procedures. This study is part of a Federal Government Research Programme. Your help in completing the questionnaire is appreciated.

We do not need to know your name. Responses will be kept confidential.

Please fill out the questionnaire below by yourself without consulting others. Do it today, if possible, as soon as you return to the building. VISITORS TO THIS BUILDING SHOULD MARK "N/A" FOR QUESTIONS THAT ARE NOT APPLICABLE. IF YOU ARE A VISITOR, PLEASE TICK HERE: ☐

Seal the completed questionnaire in the envelope provided and leave it with the floor fire warden. Alternatively you can post it in the pre-addressed envelope free of charge.

For each of the following questions please circle the number beside the appropriate response. In some cases you may need to write in an answer, for example, if you select the answer "Other"

EARLY STAGES OF THE EVACUATION

Which floor were you on at the time of the evacuation?

Floor ____

On which floor do you normally work?

Floor ____

Did you have prior knowledge that an evacuation was to take place?

1. No and surprised
2. No but not surprised
3. Suspected something like a drill was to be conducted
4. Yes but time of drill was not known
5. Yes and time of drill was known

We would like to know what you were doing at the very start of the evacuation. What were you doing at the time you first noticed something out of the ordinary?

1. Working, typing (or sitting at a desk)
2. Taking out or putting something away
3. On telephone
4. In meeting
5. In transit somewhere
6. In toilet
7. Other

____
____
__

Below is a list of actions each identified by a letter of the alphabet. In the spaces provided please indicate your actions in the order they occurred from the time you were first aware of something out of the ordinary to the time when you first entered the stairs or elevator. If you did something not listed below please describe it in the extra space provided under "other".

At times people are interrupted in what they are doing and may resume or repeat actions. This can be indicated below by repeating the letter at some stage. For example, if the first thing that you did was to move to your normal position of work (desk), then went looking for information, then moved back to your work position before moving directly to the fire stairs, the first four spaces would be completed as follows:

EXAMPLE: My first action was 1 c

Select from the following list of actions;

A. Went looking for information

B. Asked someone else for information

C. Moved to normal work location (desk)

D. Organised actions of others

E. Informed others

F. Put things away

G. Closed doors/ windows

H. Gathered valuables

I. Retrieved or put on article of clothing

J. Moved directly to stairs

K. Physically assisted others

L. Observed actions of others

M. Moved to elevator

N. Waited in line (queue)

O. Other

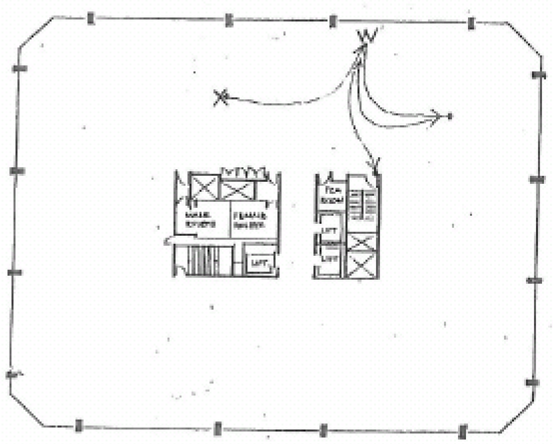
My first action was	1	____
My second action was	2	____
My third action was	3	____
My fourth action was	4	____
My fifth action was	5	____
My sixth action was	6	____
Etc.	7	____
	8	____
	9	____
	10	____

PATH OF MOVEMENT ON OFFICE FLOOR

X to indicate where you were when you first noticed something out of the ordinary

W to indicate the normal position where you work

Please indicate where you moved from the point X on the plan to the point where you exited from the floor. This should be done by drawing as accurately as you can your path of movement on the plan. Please put in arrows to indicate the direction of your movement so that we can follow this when we look at the plan. Your movement shold look something like the example on the right.



EXAMPLE PLAN

PLEASE TURN OVER THIS PAGE TO COMPLETE THE PLANS IF YOU WERE ON A FLOOR BETWEEN:

LEVELS 1-14: **COMPLETE PLAN "A"**

LEVELS 17-32 **COMPLETE PLAN "B"**

MOVEMENT INTO AND ON THE STAIRS

Please circle the number that best describes the extent to which you <u>disagree</u> or <u>agree</u> with each of the following statements:

	Strongly disagree	Disagree	Are neutral	Agree	Strongly agree
The stair was easy to find	1	2	3	4	5
Your time in the stair seemed too long	1	2	3	4	5
The stair was too hot	1	2	3	4	5
The stair was too cold	1	2	3	4	5
The stair was uncomfortably crowded	1	2	3	4	5
You felt hemmed in whilst in the stair	1	2	3	4	5
The speed of movement was too fast	1	2	3	4	5
The speed of movement was too slow	1	2	3	4	5
The stair was too steep	1	2	3	4	5
The steps were too slippery	1	2	3	4	5
The handrail was awkward to use	1	2	3	4	5
The stair lighting was inadequate	1	2	3	4	5
The stair's general appearance, including colour, was unpleasant	1	2	3	4	5

Viewing panels should be added to the fire doors on each level	1	2	3	4	5

Please indicate with a circled number the extent to which you experienced the conditions listed below:

	Not at all	Slightly	Moderate	Very much	An extreme degree
Delay due to the number of people waiting on your floor to enter the stair	1	2	3	4	5
Difficulty in exerting enough force to open the door into the stair	1	2	3	4	5
Difficulty with the door swing endangering people already in the stair	1	2	3	4	5
Delay in waiting for people coming down from higher floors to pass your floor or to allow to move in with them	1	2	3	4	5
Delay because people in front of you walked too slowly down the stair	1	2	3	4	5

RECONSTRUCTED QUESTIONS FROM CODING SHEETS CONCERNING PHYSICAL

CHARACTERISTICS OF RESPONDENTS, THEIR MOVEMENTS AND REACTIONS

What is your mass in kilograms (weight)? ______________kgs.

What is your height in centimetres? ___________________cms.

Are you male or female?

1. Male
2. Female

What size shoes do you wear? (Please state whether size is UK, Europe or other)

____

How long have you been working in this building? (Note number of years and months below)

____

Are you a fire warden now?

1. No
2. Yes

Have you been a fire warden in the past?

1. No
2. Yes

If "yes" how long did you act in this position? (Note in months_________________________

If you are presently a warden what is your role? (Answer in the space provided below)

____

____

__

Regarding your current employment what position do you hold?

____

____

__

How many people work in your section? (Note number)

____

What position in the organisation does your immediate superior hold?

____

____

__

What is the position of the person in your organisation to whom your superior reports?

____

____

__

	Not at all	Slightly	Moderate	Very much	An extreme degree
You were apprehensive about your safety whilst going down the stairs	1	2	3	4	5
You were apprehensive about gaining a safe footing on the narrow treads	1	2	3	4	5
You were concerned about brushing against the walls whilst going down the stairs	1	2	3	4	5
Pain in your knees after going down the stairs	1	2	3	4	5
Weakness in your knees after going down the stairs	1	2	3	4	5
Discomfort or tightness in your chest after going down the stairs	1	2	3	4	5
You were generally fatigued after going down the stairs	1	2	3	4	5
At any time did you feel dizzy or that you were going to lose your balance	1	2	3	4	5
You used the handrail whilst going down the stairs	1	2	3	4	5
The stair was not wide enough	1	2	3	4	5

Why did you choose the exit you left the floor by?

1. Most familiar exit
2. Directed to exit by warden
3. Directed to exit other than by warden
4. Followed others to exit
5. It was the nearest exit
6. No particular reason
7. Other

____

____

__

We would also like to know a little more about your use of the door into the stair. Please indicate which of the following applies:

1. The door was held open by someone else
2. The door was held open by a wedge
3. you opened the door yourself without any difficulty
4. You required assistance to open the door
5. The door could not be opened

If the door could not be opened, please indicate how you managed to leave that floor:

1. Used another stair
2. Used elevator
3. Stayed on floor
4. Other
____
____
__

We are interested in whether or not you kept close to anyone in particular at any stage during the evacuation.

Firstly did you accompany anyone in particular to the stair?

1. No
2. Yes

If "yes" how many individuals? ________

Were these individual well known to you?

1. No
2. Yes

Did you leave the stair at the bottom with at least one individual nearby that entered the stair with you?

1. No
2. Yes

If you kept close to anyone in particular at any stage where did you first form this contact (e.g. start conversing) during the evacuation?

1. At your desk
2. In the office space generally
3. In the office corridor
4. At the entrance to the stairs
5. On the stair
6. At the bottom of the stair
7. At the final exit from the building
8. Other ____

Were you held up by fire brigade personnel coming up the stairs while you were going down?

1. No
2. Yes

If “yes” how many fire brigade personnel were there? _____________

Were you overtaken by others while going down the stairs?

1. No
2. Yes

If “yes” how many overtook you? ________________

Did you have any difficulties in going down the stairs that you have not told us about as yet?

____

Please indicate how many storeys of stairs you feel capable of walking down without stopping, at a normal speed and without assistance:

1. None
2. 1-2 storeys
3. 3-5 storeys
4. 6-9 storeys
5. 10-14 storeys
6. 15-19 storeys
7. 20 or more

Do you have any physical disabilities that impair your ability to walk up or down stairs?

1. No
2. Yes

If "yes", please describe:

____

____

__

If you use a stair rather than the lift in this building for normal circulation please indicate why. (Circle one or more).

1. Have4 no particular reason for the choice
2. Elevators are too crowded
3. Generally dislike elevators
4. Occasionally for the physical exercise
5. At every opportunity for the exercise
6. Stairway provides a more direct route of travel
7. Waiting time for elevators is too long
8. Elevators move too slowly
9. Other

How often do you go to a floor of the building other than the one on which you work?

1. Never
2. Less than once per day
3. 1-2 times per day
4. 3-5 times per day
5. 6 or more times per day

What is the maximum number of storeys that would be involved in these trips?

PLEASE NOTE T5HAT ALL QUESTIONS DEALING WITH KNOWLEDGE OF FIRE SAFETY AND CONFIDENCE IN THE OPERATION OF THE BUILDING FIRE SAFETY SYSTEM HAVE NOT BEEN SHOWN AS THE ISSUES ARE OUTSIDE THE SCOPE OF THE EXPLORATORY CASE STUDY

A3.2 CYCLE ONE – NRCC MODEL WITH FITNESS FOLLOW-UP

The NRCC Model questionnaire resembles the one referred to in the Exploratory Case Study and used with Buildings M1 and M2. The format on the following pages is altered from the original questionnaire because of the page layout used in this Thesis. The Arial font has been maintained.

The two questionnaires proved to be too difficult to administer so that the format was revised for PDSA Cycle 2 (see A3.2).

Memorandum to Building XXX CLIENTS

Date: DD/MM/2009

To: Stair Users and Questionnaire Respondents

From: Building XX Management Team and the Research Team - University of Salford.

RE: **TRIAL EVACUATION STUDY AT XXX Building – HELD AT 11AM DD/MM/2009**

This trial evacuation is essential for your safety in this your building. By taking part in it and responding to the questionnaire you will help Building XX Management Team by providing them with feedback on the building and the emergency procedures. This trial evacuation is also being included as part of an international research project on the use of stairs in evacuation.

Trial evacuations are being monitored in four countries. This involves the handing out and voluntary completion of questionnaires which ask certain questions that are vital to the study. The monitoring of each evacuation also involves the gathering of visual information about the pattern and speed of movement of the building occupants on the stairs. This information will be recorded on miniature video cameras positioned in the stairs which are only capable of catching outline images. None of these images will ever be published or used in reports. The images are being turned into numerical data and direct observations for future analysis. One the analysis is finished the video footage will be destroyed. A written undertaking has been given to Building XX Management to this effect.

The questionnaires will have been delivered by Hamish MacLennan to each one of your offices before the evacuation. Please note that the questionnaire is made up of two parts:

1. Main Questionnaire: Sections 1-3 to be completed on 26 August 2009 and will be picked up personally by Hamish MacLennan on the 27 August 2009 from your office.
2. A follow up Questionnaire to see how you feel physically after two days will be delivered to your office on the 27 August 2009 and is to be completed for pick up by Hamish on the 29 August 2009 from your office.

Building XX Management supports and will make use of this research to improve your safety.

The research is being carried out by a Research Team at one of the UK's leading Universities, University of Salford, in Inclusive Design which really means designing for everyone in the population and to include their needs. Joe Smith your Building Manager and his team from Building XX Management are participating jointly with Hamish in the programme.

We would really appreciate your help in this project in order to provide top value for each one of you and to increase your sense of safety in the building and its emergency systems. The outcomes will also be vital in helping those building occupants who are not really capable of using the stairs establish another acceptable and safe way of evacuating the Building.

What will happen?

You will follow your normal procedures. The questionnaires will have been delivered to your offices by Hamish immediately after the completion of the evacuation. Your Office Manager or equivalent will know all about it. We would really appreciate about 10 minutes of your time whilst everything is still fresh in your mind to complete the questionnaire. When you have completed it please return it to the Receptionist in your Office so that Hamish can pick it up. Don't forget that there will be a follow up questionnaire that will be handed out to your Office Receptionist on the 27th August. Remember that this follow up questionnaire is to see how you are feeling as a result of the evacuation. Please pick up a copy and complete it and give it back to your Receptionist so that Hamish can pick it up on the 29th August.

Thank you very much for your help.

Kind Regards

Hamish

Hamish MacLennan

Researcher

University of Salford

Joe

Joe Smith
Building Manager
Building XX

QUESTIONNAIRE ONE – ON THE DAY

SECTION ONE – WHILE YOU WERE ON THE FLOOR

Q1. Did you hear the fire alarm? (circle as appropriate)

Yes No

Q2. In your opinion was the fire alarm?

A; too loud **B**; loud enough **C**; too quiet – *circle the appropriate letter*

Q3. Which floor were you on when the fire alarm sounded? (insert the floor number between the brackets (   )

Q4. Was the stair you used your normal designated stair? Circle as appropriate.

Yes No

Q5. Was this stair your closest stair? Circle as appropriate

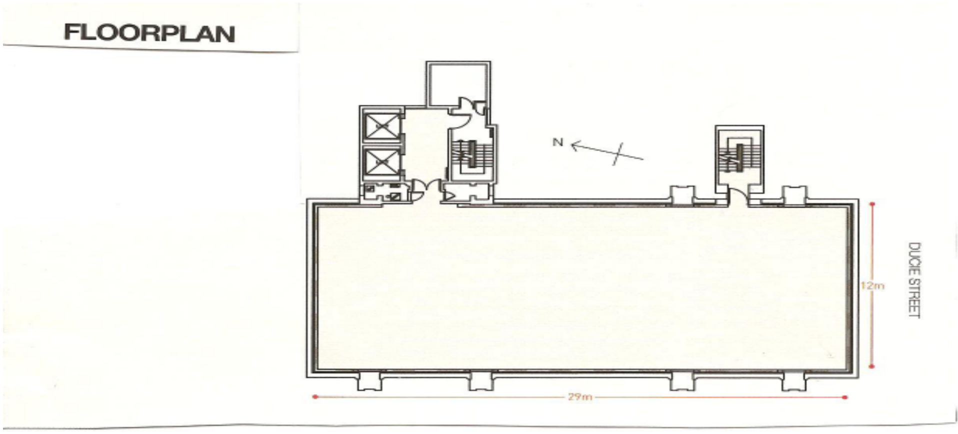
Yes No

Q6. Which of the following activities did you carry out before you entered the stairs? Please answer by placing a (✔) in the appropriate column alongside each statement:

Statement	**Yes**	**No**
A. Returned to your office		
B. Continued working		
C. Sought more information		
D. Used phone to contact someone outside the building		
E. Secured files/ shut down computer/ secured information		
F. Gathered valuables		
G. Put on additional clothing		
H. Talked with a colleague		
I. Followed the instructions of a warden		
J. Other – please describe below: …………………………………………………………………….. …………………………………………………………………….. …………………………………………………………………….. …………………………………………………………………….. ……………………………………………………………………..		

Q7. Please complete the following tasks:

- **(a)** **Circle the door by which you entered the stair you used for the evacuation**
- **(b)** **Mark your location on the floor at the beginning of the evacuation with an 'X'**
- **(c)** **Mark the approximate route you followed to reach the stair you used with a dotted line or similar.**



Proceed to Question 8 over page

Q8. How much time did you spend on the floor from when the fire alarm sounded until you reached the door to the stairs? *This estimate is not to include the time you spent standing at the door waiting for others.*

Indicate your estimate in the space provided below in minutes and seconds to the nearest 30 seconds. _______minutes: _________ seconds

Q9. Did you require assistance to evacuate? Circle as appropriate:

Yes No

Q10. Did you have to wait to enter the stairs? (circle the appropriate letter)

A. Because you were told to by the fire warden

B. There were people coming down from the floor above

C. You were held up mixing with people coming down from another floor above.

D. You were held up by the number of people from your own floor entering the stair all at the one time.

E. You were not held up.

Q11. How long did you have to wait before you entered the stairs?

Enter your estimate in the space provided – to the nearest 30 seconds:

_______minutes: ________ seconds

Q12. Did you enter the stairs with a friend? Circle as appropriate:

Yes No

Q13. If you answered yes to question 12 then where did you meet this friend or colleague? Circle appropriate letters:

A. On the floor

B. As you entered the stairs

C. Other – describe in the space provided below:

……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

Q14. Having just completed this trial evacuation what is the maximum number of floors that you would be able to cope with without taking a rest?

Please insert the number of floors and any other comment you wish to make in answer to this question:

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
………......

Q15. Having just completed this trial evacuation what is the maximum number of floors that you would be able to cope with WITHOUT TAKING A REST?

Please insert the number of floors and any other comment you wish to make in answer to this question.

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………

SECTION TWO: WHILST YOU WERE GOING DOWN THE STAIRS

Q16. Indicate your degree of agreement or otherwise with the following statements? Please answer by placing a (✔) in the appropriate column alongside each statement.

No.	Statement	Strongly Agree	Mildly Agree	Mildly Disagree	Strongly Disagree
A.	The handrail was easy to find				
B.	The first step of each flight was easy to find				
C.	Each step was easy to locate				
D.	The last step in each flight was easy to locate				
E.	The stairs were too steep				
F.	The steps were too small				
G.	There were too many flights of steps to cope with				
H.	You suffered some discomfort or soreness in your lower legs				
I.	You felt dizzy and could have fallen				
J.	You were out of breath				
K.	You suffered some discomfort in your chest				
L.	You had some pain in your knees				
M.	You were generally tired				

Q17. Did you feel comfortable going down the stairs? (circle as appropriate)

Yes No

Q18. If you answered 'No' please comment in the space provided below:

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
……………………………………………………………

Q19. How you would you describe the conditions around you in the stairs? (Circle the appropriate letter):

A. very crowded and slow **B.** crowded but moving well **C.** few others around **D.** I was alone

Q20. How much time did it take you to evacuate the building from the time the alarm sounded to when you exited through the last door in the stairwell to outside the building? Your estimate should be to the nearest 30 seconds.

________minutes _______ seconds

SECTION THREE – ABOUT YOU

Q21. On which floor do you normally work? *Insert floor number (   )*

Q22. On which floor and Office were you at the beginning of this evacuation? *Insert floor number (   )*

Q23. Which stair do you normally use for evacuation? *Insert north or south (
)*

Q.24 Have you ever taken part in an evacuation before? (*Circle as appropriate)*

Yes No

Q25. If your answer to question 24 is 'yes', please indicate in the brackets provided the number of trial evacuations you have taken part in over the last three years. *Insert number (   )*

Q26. Using your experience of this evacuation what is the maximum number of floors you think you would be able to evacuate in the future without holding others up or where you would feel unsafe because of the number of people in the stairs wanting to pass you: Insert No. of floors in the space between the brackets. (   )

Q27 In what year in were you born? (e.g. 1973 etc. Insert the year between the brackets)

(   )

Q28. Your Gender? (circle as appropriate) Male Female

Q29. What is your height? Please use the units of measurement you are comfortable with and insert between the brackets. (   )

Q30. What is your approximate weight? Please use the units of measurement you are comfortable with and insert between the brackets.   (   )

Q31. What size shoes do you wear? Please use UK/US or European sizes i.e. the size noted on the shoes you were wearing and insert between the brackets.   (
)

Q32. How often have you fallen in the last 3 years? Insert number between the brackets. (   )

Q33. If you have fallen over the last year, then please give us much detail of the falls that you can remember in the table below:

Fall No.	When?	Details
1		
2		
3		
4		
5		
6		
7		

Q33 (continued) Any other comments you wish to make:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
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…………………………………………

Please proceed to Q 34 on the next page

Q34: Do you have any of the following condition(s)? Please answer by placing a (✔) in the appropriate column alongside the condition(s) you may have:

No.	Condition	Yes	No
A.	Heart condition		
B.	Asthma or breathlessness		
C.	Prior stroke		
D.	Diabetes (Type 1 or 2)		
E.	Problem with your balance		
F.	Arthritis in lower limbs		
G.	Reduced mobility		
H.	Injury that interferes with you walking quickly		
I.	Hearing loss		
J.	Reduced vision		
K.	Loss of memory		
L.	Unable to handle more than one task at a time.		
M.	Fear of falling		
N.	Fear of crowds		
O.	Other (Please state) ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ……………………………………………………………… ………………………………………………………………		

Questionnaire 2 - A FOLLOW UP QUESTIONNAIRE TO SEE HOW YOU ARE FEELING AFTER THE EVACUATION TWO DAYS AGO? (some questions are repeated from Questionnaire 1. Please help us by completing them again as Questionnaire 2 will be separated from your Questionnaire 1.)

Q1. **On which floor do you normally work?** (   ) *Insert floor number*

Q2. **Which floor were you on when the fire alarm sounded** (   ) *Insert floor number*

Q3. After this evacuation especially with the way you feel now e.g. muscle stiffness, general fatigue or any other complications, what is the maximum number of stories that would be able to evacuate without holding others up or where you feel unsafe (Please insert the maximum number between the brackets (   )

Q4. Do you have any of the following conditions (circle appropriate 'letter')**?**

A. Heart Condition

B. Asthma

C. Arthritis in legs or feet

D. Arthritis elsewhere

E. Injury that interferes with using the stairs

F. Overweight

G. Hearing impairment

H. Vision impairment

I. Mobility impairment

J. Diabetes

K. Ear Infections

L. Other – please comment below:

Q5. What year were you born? (insert the year between the brackets): (
)

Q6. Your Gender? (Circle as appropriate) Male Female

Q7. What is your height? (Please insert between the brackets ( )

Q8. **What is your approximate weight?** (Please insert between the brackets) (
)

Q9. What size shoes do you wear? (Please insert between the brackets using the size indicated in your shoe): ( )

Q10. How often have you fallen in the last 3 years? (Insert number between the brackets) ( )

Q11. If you have fallen over the last 1 year, then please give us much detail of the falls that you can remember in the table below:

Fall No.	When?	Details including the reasons?
1		
2		
3		
4		
5		
6		
7		

Additional Comments:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

Q12. How far do you walk each day? Please insert the distance covered (
)

Q13. How many trips are involved in your answer to Question 12? Please insert no. ( )

Q14. Do you have any difficulty going down the stairs in this building? *(Circle the appropriate letter)*

A Always **B** Most of the time **C** Sometimes **D** Rarely **E** Never

Q15. Do you go up or down stairs each day? (Circle as appropriate)

A Always **B** Most of the time **C** Sometimes **D** Rarely **E** Never

Q16. If you circled 'A' to 'D' in your answer to Q15 then how many flights are involved? Insert the number inside the appropriate brackets:

Going up – No. of flights ( ) **Going down - No. of flights ( )**

(if you ascend and descend each day then insert an amount under each heading).

Q17. **Do you use the handrail when you go down the stairs?** *(Circle the appropriate letter)*

A Always **B** Most of the time **C** Sometimes **D** Rarely **E** Never

Q18. Following the evacuation 2 days ago, do you have any muscle pain or soreness? (*Circle as appropriate*). Yes No.

Q19. If so please indicate the location(s) of this pain/soreness?

A – rear of hip region **B** - front thigh **C** -back thigh **D**- back **E**- feet **F**- back of lower leg **G** – Other:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………………………………………………………………

Q20. Are you suffering from any other after affects? Please write your answer in the space provided below:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………

Q21. In the two months before evacuation have you done any downhill running or walking? (*Circle the appropriate letter)*

A Yes, on one occasion **B** Yes, on more than one occasion **C** No, not all.

Q22. In the two months before the evacuation have you gone down the stairs? (*Circle the appropriate letter)*

A Yes, on one occasion **B** Yes, on more than one occasion **C** No, not all.

A3.3 CYCLE TWO – NRCC MODEL WITH FITNESS FOLLOW-UP ABSORBED INTO MAIN QUESTIONNAIRE

The NRCC Model questionnaire from PDSA Cycle 1 was modified and the fitness related questions absorbed into the main questionnaire. This was following the decision that a variable known as METS could be computed from other associated variables such as a combination of BMI and health conditions.

Memorandum to Majestic Building Tenants and Occupants

Date: 26/11/2008

To: Stair Users and Questionnaire Respondents

From: Building Owner Management; the Research Team - University of Salford.

RE: **TRIAL EVACUATION STUDY AT MAJESTIC BUILDING – 26 NOVEMBER - 2008**

The trial evacuation you have just taken part is essential for your safety in this building. Filling out the attached questionnaire will help your Building Emergency Management Organisation by providing them with feedback on the Building Emergency Evacuation procedures. It won't take you any longer than 10 minutes.

This trial evacuation is also being included as part of an international research project on the use of stairs in evacuation.

Trial evacuations are being monitored in a number of countries. This involves the handing out and voluntary completion of questionnaires which ask you certain questions that are vital to the study. The monitoring of each evacuation also involves the gathering of visual information about the how you as the building occupants move down the stairs. This information will be recorded on miniature video cameras positioned in the stairs which will only record an outline image of each of you. None of the recorded images will ever be published or used in reports in strict accordance with the UK Data Protection Act. The images are being used for detailed analysis. One this analysis is finished the video images will be destroyed. A written undertaking has been given to the Building Owner and Manager to this effect. This will ensure the protection of your privacy and compliance with the Act.

The attached questionnaire contains information that will be used to establish possible improvements that can be made to the way we provide for evacuation in buildings.

The research is being carried out by Hamish MacLennan at the University of Salford, in Inclusive Design which really means designing for and including the needs of everyone in the population. Hamish has been involved in stair safety research since 1980. At a late time in his life is completing his PhD at the University of Salford. SOS Property Services are running this evacuation jointly with Hamish and taking part in the research programme.

We would be grateful if you could complete the attached questionnaire and return this back to the team who provided this to you or to the front desk of your office from where it will be collected over the next few days.

The Building Emergency Management Organisation supports this research and will make use of it to improve your safety.

We would really appreciate your help in this project in order to provide top value for each one of you and to increase your sense of safety in the building and its emergency systems. The outcomes will also be vital in helping those building occupants who are not really capable of using the stairs establish another acceptable and safe way of evacuating the Building.

Thank you very much for your help.

Kind Regards

Hamish

Hamish MacLennan

Researcher

University of Salford

SECTION ONE – WHILE YOU WERE ON THE FLOOR

Q1. Did you hear the fire alarm? (circle as appropriate)

Yes No

Q2. In your opinion was the fire alarm?:

A; too loud **B**; loud enough **C**; too quiet – *circle the appropriate letter*

Q3. Which floor were you on when the fire alarm sounded? (insert the floor number between the brackets ( )

Q4. Was the stair you used your normal designated stair? Circle as appropriate.

Yes No

Q5. Was this stair your closest stair? Circle as appropriate

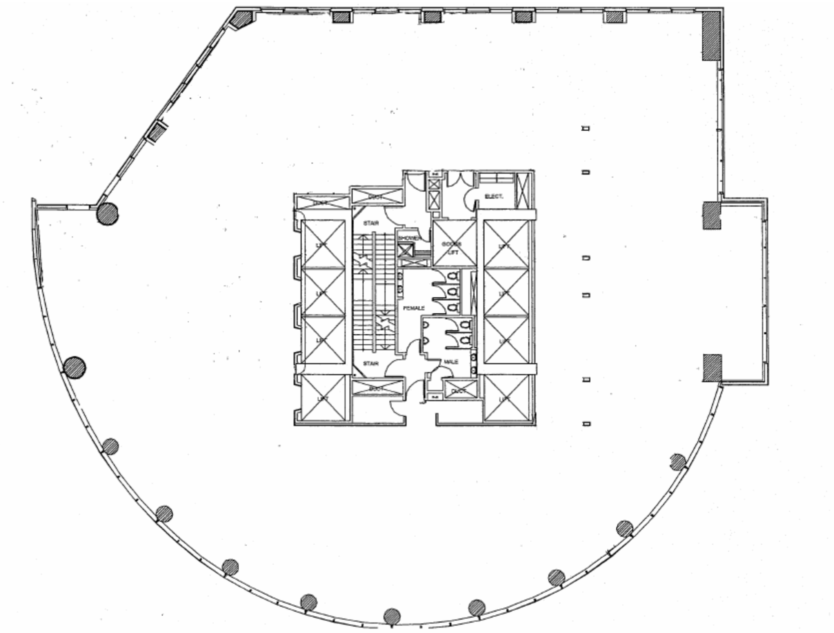
Yes No

Q6. Which of the following activities did you carry out before you entered the stairs? Please answer by placing a (✔) in the appropriate column alongside each statement:

Statement	**Yes**	**No**
A. Returned to your office		
B. Continued working		
C. Sought more information		
D. Used phone to contact someone outside the building		
E. Secured files/ shut down computer/ secured information		
F. Gathered valuables		
G. Put on additional clothing		
H. Talked with a colleague		
I. Followed the instructions of a warden		
J. Other – please describe below: ………………………………………………………………….. ………………………………………………………………….. ………………………………………………………………….. ………………………………………………………………….. …………………………………………………………………..		

Q7. Please complete the following tasks:

- **(d)** **Circle the door by which you entered the stair you used for the evacuation**
- **(e)** **Mark your location on the floor at the beginning of the evacuation with an 'X'**
- **(f)** **Mark the approximate route you followed to reach the stair you used with a dotted line or similar.**



Proceed to Question 8 over page

Q8. How much time did you spend on the floor from when the fire alarm sounded until you reached the door to the stairs? *This estimate is not to include the time you spent standing at the door waiting for others.*

Indicate your estimate in the space provided below in minutes and seconds to the nearest 30 seconds. _______minutes: _________ seconds

Q9. Did you require assistance to evacuate? Circle as appropriate:

Yes No

Q10. Did you have to wait to enter the stairs? (circle the appropriate letter)

A. Because you were told to by the fire warden

B. There were people coming down from the floor above

C. You were held up mixing with people coming down from another floor above.

D. You were held up by the number of people from your own floor entering the stair all at the one time.

E. You were not held up.

Q11. How long did you have to wait before you entered the stairs?

Enter your estimate in the space provided – to the nearest 30 seconds:

_______minutes: ________ seconds

Q12. Did you enter the stairs with a friend? Circle as appropriate:

Yes No

Q13. If you answered Yes to question 12 then where did you meet this friend or colleague? Circle appropriate letters:

A. On the floor

B. As you entered the stairs

C. Other – describe in the space provided below:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
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……………………………………………………………………………………………
……………………………………………………………………………………………
………………

Q14. Having just completed this trial evacuation what is the maximum number of floors that you would be able to cope with without taking a rest?

Please insert the number of floors and any other comment you wish to make in answer to this question:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
…………......

SECTION TWO: WHILST YOU WERE GOING DOWN THE STAIRS

Q16. Indicate your degree of agreement or otherwise with the following statements? Please answer by placing a (✔) in the appropriate column alongside each statement.

No.	Statement	Strongly Agree	Mildly Agree	Mildly Disagree	Strongly Disagree
A.	The handrail was easy to find				
B.	The first step of each flight was easy to find				
C.	Each step was easy to locate				
D.	The last step in each flight was easy to locate				
E.	The stairs were too steep				
F.	The steps were too small				
G.	There were too many flights of steps to cope with				
H.	You suffered some discomfort or soreness in your lower legs				
I.	You felt dizzy and could have fallen				
J.	You were out of breath				
K.	You suffered some discomfort in your chest				
L.	You had some pain in your knees				
M.	You were generally tired				

Q17. Did you feel comfortable going down the stairs? (circle as appropriate)

Yes No

Q18. If you answered 'No' please comment in the space provided below:

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
……………………………………………………………………

Q19. How you would you describe the conditions around you in the stairs? (Circle the appropriate letter):

A. very crowded and slow **B.** crowded but moving well **C.** few others around **D.** I was alone

Q20. How much time did it take you to evacuate the building from the time the alarm sounded to when you exited through the last door in the stairwell to outside the building? Your estimate should be to the nearest 30 seconds.

________minutes _______ seconds

SECTION THREE – ABOUT YOU

Q21. On which floor do you normally work? *Insert floor number (   )*

Q22. On which floor and Office were you at the beginning of this evacuation? *Insert floor number (   )*

Q23. Which stair do you normally use for evacuation? *Insert north or south (   )*

Q.24 Have you ever taken part in an evacuation before? (*Circle as appropriate)*

Yes   No

Q25. If your answer to question 24 is 'yes', please indicate in the brackets provided the number of trial evacuations you have taken part in over the last three years. *Insert number (   )*

Q26. Using your experience of this evacuation what is the maximum number of floors you think you would be able to evacuate in the future without holding others up or where you would feel unsafe because of the number of people in the stairs wanting to pass you: Insert No. of floors in the space between the brackets.   (   )

Q27 In what year in were you born? (e.g. 1973 etc. Insert the year between the brackets)

(   )

Q28. Your Gender? (circle as appropriate)   Male   Female

Q29. What is your height? Please use the units of measurement you are comfortable with and insert between the brackets. (   )

Q30. What is your approximate weight? Please use the units of measurement you are comfortable with and insert between the brackets.   (   )

Q31. What size shoes do you wear? Please use UK/US or European sizes i.e. the size noted on the shoes you were wearing and insert between the brackets.   (
)

Q32. How often have you fallen in the last 3 years? Insert number between the brackets. (   )

Q33. If you have fallen over the last year, then please give us much detail of the falls that you can remember in the table below:

Fall No.	When?	Details
1		
2		
3		
4		
5		
6		
7		

Q33 (continued) Any other comments you wish to make?

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
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……………………………………………………………………………………………
……………………………………………

Please proceed to Q 34 on the next page

SECTION FOUR – HOW YOU FELT THE DAY AFTER THE EVACUATION

Q34: Do you have any of the following condition(s)? Please answer by placing a (✔) in the appropriate column alongside the condition(s) you may have:

No.	Condition	Yes	No
A.	Heart condition		
B.	Asthma or breathlessness		
C.	Prior stroke		
D.	Diabetes (Type 1 or 2)		
E.	Problem with your balance		
F.	Arthritis in lower limbs		
G.	Reduced mobility		
H.	Injury that interferes with you walking quickly		
I.	Hearing loss		
J.	Reduced vision		
K.	Loss of memory		
L.	Unable to handle more than one task at a time.		
M.	Fear of falling		
N.	Fear of crowds		
O.	Other (Please state) …………………………………………………………… …………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………………		

Q35. Do you have any difficulty going down the stairs in this building? *Circle the appropriate letter.*

A Always **B** Most of the time **C** Sometimes **D** Rarely **E** Never

Q36. Do you go up or down stairs each day? *Circle the appropriate letter.*

A Always **B** Most of the time **C** Sometimes **D** Rarely **E** Never

Q37. If you circled 'A' to 'D' in your answer to Q36 then how many flights are involved? Insert the number inside the appropriate brackets:

Going up – No. of flights (   ) **Going down - No. of flights (   )**

(if you go both up and down each day then insert an amount under each heading).

Q37. **Do you use the handrail when you go down the stairs?** *Circle the appropriate letter.*

A Always **B** Most of the time **C** Sometimes **D** Rarely **E** Never

Q38. Following the evacuation 2 days ago, do you have any muscle pain or soreness? *Circle as appropriate* Yes No.

Q39. If so please indicate the location(s) of this pain/soreness?

A – rear of hip region **B** - front thigh **C** -back thigh **D**- back **E**- feet **F**- back of lower leg **G** – Other:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………

Q40. Are you suffering from any other after affects? Please write your answer in the space provided below:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
……………………

Q41. In the two months before evacuation have you done any downhill running or walking? *Circle the appropriate letter.*

A Yes, on one occasion **B** Yes, on more than one occasion **C** No, not at all.

Q42. In the two months before the evacuation have you gone down the stairs? *Circle the appropriate letter.*

A Yes, on one occasion **B** Yes, on more than one occasion **C** No, not at all.

A3.4.1 CYCLE THREE – NRCC FURTHER MODIFIED AND SHORT FORM IPAQ

The questionnaire for PDSA Cycle 3 for M5 and M6 was again modified from that administered in PDSA Cycle 2. This modification included the Short Form International Physical Activity Questionnaire designed and validated as a reliable self reporting tool by Sjostrom et al (2005).

Memorandum to Survey Participants

University of Salford
A Greater Manchester University

Date: 30/01/2009

To: Stair Users and Questionnaire Respondents

From: The Research Team - University of Salford.

RE: **TRIAL EVACUATION STUDY AT Unisys Building, Wellington on the 30/01/2009**

This trial evacuation is essential for your safety in this your building. By taking part in it and responding to the questionnaire you will help the Research Team by providing them with feedback on the emergency evacuation procedures. This trial evacuation is part of an international research project on the use of stairs in evacuation.

Trial evacuations are being monitored in three countries. This involves the handing out and voluntary completion of questionnaires which ask certain questions that are vital to the study. The monitoring of each evacuation also involves the gathering of visual information about the pattern and speed of movement of the building occupants on the stairs. This information will be recorded on miniature video cameras positioned in the stairs which are only capable of catching outline images. None of these images will ever be published or used in reports. The images are being turned into numerical data and direct observations for future analysis. One the analysis is finished the video footage will be destroyed. A written undertaking has been given to the Building Management and Owner to this effect.

The research is being carried out by a Research Team at one of the UK’s leading Universities, University of Salford, in Inclusive Design which really means designing for everyone in the population and to include their needs. The researcher, Hamish MacLennan is completing his PhD at the University of Salford.

We would really appreciate your help in this project. The outcomes will also be vital in helping those building occupants who are not really capable of using the stairs establish another acceptable and safe way of evacuating the Building.

What will happen?

You will have followed your normal procedures. The questionnaires will have been delivered to your offices immediately after the completion of the evacuation. Your Office Manager or Fire Warden will know all about it. We would really appreciate it if you could spend about 15 minutes of your time on the day after the evacuation whilst everything is still fresh in your mind to complete the questionnaire. When you have completed it please return it to the Receptionist in your Office.

Thank you very much for your help.

Kind Regards

Hamish

Hamish MacLennan

Researcher, University of Salford

University of Salford
A Greater Manchester University

AN INTERNATIONAL STUDY INTO THE CAPABILITY OF PEOPLE TO DESCEND MULTIPLE FLIGHTS OF STAIRS

TRIAL EVACUATION

AND

FITNESS

QUESTIONNAIRE

PLEASE COMPLETE THIS QUESTIONNAIRE 24HRS AFTER COMPLETING THE TRIAL EVACUATION

SECTION ONE – ABOUT YOU

Q1. On which floor do you normally work? *Insert floor number ( ).*

Q2. On which floor were you when you heard the fire alarm at the beginning of this evacuation? *Insert floor number ( ).*

Q3. In what year were you born? (e.g. 1973.) *Insert the year between the brackets ( ).*

Q4. Your Gender? *(Circle as appropriate)* Male Female.

Q5. What is your height? *Insert in feet and inches or centimetres and insert between the brackets* (*).*

Q6. What is your approximate weight or mass? *Insert between the brackets ( ).*

Q7. What size shoes do you wear? *Insert between the brackets using the size the size indicated in your shoe ( ).*

Q8. Do you have any of the following condition(s)? Please answer by placing a (✔) in the appropriate column alongside the condition(s) you may have

No.	Condition	Yes	No
A.	Heart condition		
B.	Asthma or breathlessness		
C.	Prior stroke		
D.	Diabetes (Type 1 or 2)		
E.	Problem with your balance		
F.	Arthritis in lower limbs		
G.	Reduced mobility		
H.	Injury that interferes with you walking quickly		
I.	Hearing loss		
J.	Reduced vision		
K.	Loss of memory		
L.	Unable to handle more than one task at a time.		
M.	Fear of falling		
N.	Fear of crowds		
O.	Other (Please state) …………………………………………………………… …………………………………………………………… …………………………………………………………… …………………………………………………………… ……………………………………………………………		

Q9. **How often have you fallen in the last twelve months?** *Insert the number between the brackets (   ).*

Q10. **If you have fallen over the last year, then please give us much detail of the falls that you can remember in the table below:**

Fall No.	When?	Details
1		
2		
3		
4		
5		
6		
7		

Any other comments you wish to make:

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………
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SECTION TWO – THE TRIAL EVACUATION

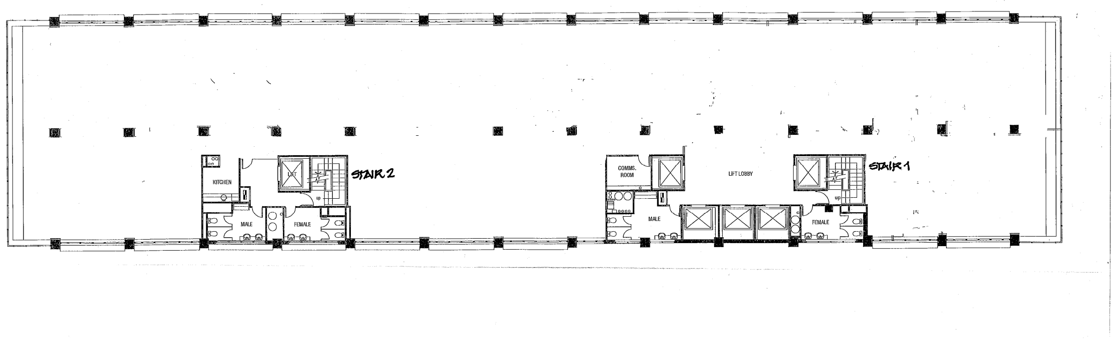
Q11. Was the stair you used your normal designated stair? *Circle as appropriate.* Yes No

Q12. Was this stair your closest stair? *Circle as appropriate.* Yes No

Q13. Please complete the following tasks:

- **(g) Circle the door by which you entered the stair you used for the evacuation**
- **(h) Mark your location on the floor at the beginning of the evacuation with an 'X'**
- **(i) Mark the approximate route you followed to reach the stair you used with a dotted line or similar.**

Insert Floor Plan



Q14. How much time did you spend on the floor from when the fire alarm sounded until you reached the door to the stairs? *This estimate is not to include the time you spent standing at the door waiting for others.*

Indicate your estimate in the space provided below in minutes and seconds to the nearest 30 seconds. _______minutes: _________ seconds

Q15. Did you require assistance to evacuate? Circle as appropriate:

Yes No

Q16. Did you have to wait to enter the stairs? (circle the appropriate letter)

A. Because you were told to by the fire warden

B. There were people coming down from the floor above

C. You were held up mixing with people coming down from another floor above.

D. You were held up by the number of people from your own floor entering the stair all at the one time.

E. You were not held up.

Q17. How long did you have to wait before you entered the stairs?

Enter your estimate in the space provided – to the nearest 30 seconds:

_______minutes: ________ seconds

Q18. Did you enter the stairs with a friend? Circle as appropriate:

Yes No

Q19. If you answered yes to question 12 then where did you meet this friend or colleague? Circle appropriate letters:

A. On the floor

B. As you entered the stairs

C. Other – describe in the space provided below:

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
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………………

Q20. Having just completed this trial evacuation what is the maximum number of floors that you would be able to cope with WITHOUT TAKING A REST? *Please insert the number of floors and any other comment you wish to make in answer to this question.*

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………

Q21. This may seem to be the same question as Q20, but it is different so please read the words carefully. **Having just completed the trial evacuation what is the maximum number of floors you would be able evacuate WITHOUT SLOWING DOWN OTHERS GOING DOWN THE STAIRS WITH YOU?** *Please insert the number of floors and any other comment you wish to make in answer to this question.*

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………
………………

Q22. Indicate your degree of agreement or otherwise with the following statements? Please answer by placing a (✔) in the appropriate column alongside each statement.

No.	Statement	Strongly Agree	Mildly Agree	Mildly Disagree	Strongly Disagree
A.	The handrail was easy to find				
B.	The first step of each flight was easy to find				
C.	Each step was easy to locate				
D.	The last step in each flight was easy to locate				
E.	The stairs were too steep				
F.	The steps were too small				
G.	There were too many flights of steps to cope with				
H.	You suffered some discomfort or soreness in your lower legs				
I.	You felt dizzy and could have fallen				
J.	You were out of breath				
K.	You suffered some discomfort in your chest				
L.	You had some pain in your knees				
M.	You were generally tired				

\

Q23. Did you feel comfortable going down the stairs? *Circle as appropriate*

Yes No

Q24. If you answered 'No' to Q.23 please comment in the space provided below:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………………………………………………………………

Q25. How you would you describe the conditions around you in the stairs? *Circle the appropriate letter.*

A. very crowded and slow **B.** crowded but moving well **C.** few others around **D.** I was alone

Q26. How much time did it take you to evacuate the building from the time the alarm sounded to when you exited through the last door in the stairwell to outside the building? *Your estimate should be to the nearest 30 seconds.*

________minutes _______ seconds

SECTION THREE – YOUR LEVEL OF FITNESS *

(International Physical Activity Questionnaire – IPAQ – Short Form)

READ: You will be asked in this section about the time you spent being active in the last 7 days before the evacuation. Please answer each question even if you do not consider yourself to be an active person. Think about the activities you do at work, as part of house work and work in the garden, to get from place to place and in your spare time for recreation, exercise or sport.

READ: Now think about all the *vigorous* activities which take *hard physical effort* that you did in the last 7 days before the evacuation. Vigorous activities make breathe much harder than normal and may include heavy lifting, digging, aerobics or fast bicycling. Think only about those activities that you did for at least 10 minutes at a time.

Q27. During the last 7 days, on how many days did you do vigorous physical activities?

(a) No. of days – Insert number of days ( )

(b) Don't Know/ Not Sure – Tick between brackets if (b) is your answer ( )

(c) Refuse to answer - Tick between brackets if (c) is your answer ( )

If you answered (b) or (c) then please proceed to question 29.

Q28a. How much time did you usually spend on one of these days doing vigorous physical activities?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q28b. How much time in total would you spend over the last 7 days before the evacuation doing vigorous physical activities?

(a) Hours per week – Insert the number of hours ( )

(b) Minutes per week – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

READ: Now think about activities which take *moderate physical effort* that you did in the last 7 days before the evacuation. Moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, bicycling at a regular pace, or playing doubles in tennis. Do not include walking. Again think only about those physical activities that you did for at least 10 minutes at a time.

Q29. During the last 7 days before the evacuation, on how many days did you do moderate physical activities?

(a) No. of days – Insert number of days ( )

(b) Don't Know/ Not Sure – Tick between brackets if (b) is your answer ( )

(c) Refuse to answer - Tick between brackets if (c) is your answer ( )

If you answered (b) or (c) then please proceed to question 31.

Q30a. How much time did you spend usually spend on one of those days doing moderate physical activities?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q30b. What is the total amount of time you spent over the last 7 days before the evacuation doing moderate physical activities?

(a) Hours per week – Insert the number of hours ( )

(b) Minutes per week – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

READ: Now think about the time you spent walking in the last 7 days before the evacuation. This includes at home, at work, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise or leisure.

Q31. During the last 7 days before the evacuation, on how many days did you walk for at least 10 minutes at a time?

(a) No. of days – Insert number of days ( )

(b) Don't Know/ Not Sure – Tick between brackets if (b) is your answer ( )

(c) Refuse to answer - Tick between brackets if (c) is your answer ( )

If you answered (b) or (c) then please proceed to question 33.

Q32a. How much time did you spend usually spend walking on one of those days?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q32b. What is the total amount of time you spent walking over the last 7 days before the evacuation?

(a) Hours per week – Insert the number of hours ( )

(b) Minutes per week – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

READ: Now think about the time you spent sitting on week days during the last 7 days before the evacuation. Include the time spent at work, while doing course work or studying, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

Q33. During the last 7 days before the evacuation how much time did you usually spend sitting on a weekday?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q34. What is the total amount of time you spent sitting or lying down last Wednesday before the evacuation?

(a) Hours on Wednesday – Insert the number of hours ( )

(b) Minutes on Wednesday – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

SECTION FIVE – TIRED OR WORN OUT? – FATIGUE!

Q43. Throughout our lives, most of us have times when we feel very tired or fatigued. Have you felt unusually tired or fatigued in the last 7 days? *Circle the appropriate.* Yes No

Q44. Please rate your fatigue (weariness, tiredness) by circling the one number that best describes your fatigue directly after the evacuation.

0 1 2 3 4 5 6 7 8 9 10

No fatigue ... as bad as you can imagine

Q45. Please rate your fatigue (weariness, tiredness) by circling the one number that best describes your usual level of fatigue over a 24 hour period.

0 1 2 3 4 5 6 7 8 9 10

No fatigue ... as bad as you can imagine

Q46. Please rate your fatigue (weariness, tiredness) by circling the one number that best describes your level of fatigue the day after the evacuation.

0 1 2 3 4 5 6 7 8 9 10

No fatigue ... as bad as you can imagine

Q47. Circle the one number that best describes how during the past 24 hours after the evacuation fatigue has interfered with your:

A. General Activity

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No fatigue										as bad as you can imagine

B. Mood

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No fatigue										as bad as you can imagine

C. Walking ability

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No fatigue										as bad as you can imagine

D. Normal work

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No fatigue										as bad as you can imagine

A3.4.2 IPAQ QUESTIONNAIRE AND INSTRUCTION SHEET FOR FOCUS GROUP STUDIES

IPAQ BASED CASE STUDY

TYPICAL OFFICE WORKER

FOCUS GROUP SECTION

PARTICIPANTS INSTRUCTIONS

You have agreed to:

Participate as a member of a specialist focus group where your task will include going down a number of flights of stairs. The number of flights will equal the number of floors in the building where the test is being held multiplied by the number of flights per floor. The number of floors is to be selected by you and is to be the number that you feel you will be comfortable with.

Just before you enter the stairs:

- Switch on the tape recorder as instructed.
- Look at and record the time on your watch as you enter into the stairs by speaking into the tape recorder.
- Leave the tape recorder running until you have exited the stair.

When you are going down the stairs.

- You may exit the stairs at any point if you start to feel too tired, dizzy, unsafe etc.
- As you pass each landing say “landing”.
- When you use the handrail say “handrail”
- If you experience any discomfort at any point then just say what and where it is. The recorder will pick up the message and we will know whereabouts this experience occurred.
- As you exit the stairs say exit and record the time on you watch.

When you have completed the exercise.

You will be asked to return to the room where you were briefed. There you will be given a questionnaire which you will be required to fill and return.

Once you have completed the questionnaire you will rejoin your group and participate in d discussion about your experience and asked to express your opinions about the usability, safety and other aspects of the stairs.

Thank you very much for your help.

We will let you know if the results. If you do want us to then just tell us after the session is over.

University of Salford
A Greater Manchester University

AN INTERNATIONAL STUDY INTO THE CAPABILITY OF PEOPLE TO DESCEND MULTIPLE FLIGHTS OF STAIRS

TRIAL EVACUATION

AND

FITNESS

QUESTIONNAIRE

Focus Group

SECTION ONE – ABOUT YOU

Q1. Which floor did you start from going down the stairs? *Insert floor number ( ).*

Q2. Why did you choose this floor? *Circle the appropriate letter(s).*

A. I was instructed to.

B. It represents the number of floors that I can cope with

C. I chose it for no particular reason

D. Other

____

____

Q3. In what year were you born? (e.g. 1973.) *Insert the year between the brackets ( ).*

Q4. Your Gender? *(Circle as appropriate)* Male Female.

Q5. What is your height? *Insert in feet and inches or centimeters and insert between the brackets ( ).*

Q6. What is your approximate weight or mass? *Insert between the brackets ( ).*

Q7. What size shoes do you wear? *Insert between the brackets using the size the size indicated in your shoe ( ).*

Q8. What is your waist measurement? *Insert the measurement in feet and inches or in centimetres between the brackets. ( )*

Q9. Do you have any of the following condition(s)? Please answer

by placing a (✔) in the appropriate column alongside the condition(s) you may have:

No.	Condition	Yes	No
A.	Heart condition		
B.	Asthma or breathlessness		
C.	Prior stroke		
D.	Diabetes (Type 1 or 2)		
E.	Problem with your balance		
F.	Arthritis in lower limbs		
G.	Reduced mobility		
H.	Injury that interferes with you walking quickly		
I.	Hearing loss		
J.	Reduced vision		
K.	Loss of memory		
L.	Unable to handle more than one task at a time.		
M.	Fear of falling		
N.	Fear of crowds		
O.	Other (Please state) …………………………………………………………………… …………………………………………………………………… ………………………………………		

Q10. How often have you fallen in the last twelve months? *Insert the number between the brackets (   ).*

Q11. If you have fallen over the last year, then please give us much detail of the falls that you can remember in the table below:

Fall No.	When ?	Details
1		
2		
3		
4		
5		
6		
7		

SECTION TWO – THE TRIAL EVACUATION

Q12. Please complete the following tasks:

(j) Circle the stair that you went down
(k) Circle the door by which you entered the stair you used for the evacuation
(l) Mark your location on the floor at the beginning of the evacuation with an 'X'
(m) Mark the approximate route you followed to reach the stair you used with a dotted line or similar.

Insert Floor Plan

Q13. What was the time on watch when you entered the stairs? *Indicate in the space provided between the brackets. (   )*

Q14. Did you require assistance to go down the stairs? Circle as appropriate:

Yes No

Q14a If you answered 'Yes' to Q14 then what kind of assistance did you require? Please comment in the space provided below.

____

____

____

____

Q15. What was the time on your watch when you passed through the final door leading to outside the building on the ground floor? *Indicate in the space provided between the brackets. (   ) If you stopped and exited on any other floor please proceed to Q15a.*

Q15a What was the time on your watch when you decided to stop? *Indicate in the space provided between the brackets. (   )*

Q15b If you did go all the way down to the ground floor please indicate the floor number on which you decided to stop and leave the stair? *Indicate in the space provided between the brackets. (   )*

Q16. Having just completed this trial evacuation what is the maximum number of floors that you would be able to cope with WITHOUT TAKING A REST? *Please insert the number of floors and any other comment you wish to make in answer to this question.*

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

Q17. This may seem to be the same question as Q16, but it is different so please read the words carefully. **Having just completed the trial evacuation what is the maximum number of floors you would be able evacuate WITHOUT SLOWING DOWN OTHERS GOING DOWN THE STAIRS WITH YOU?** *Please insert the number of floors and any other comment you wish to make in answer to this question.*

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
………………

Q18. Indicate your degree of agreement or otherwise with the following statements? Please answer by placing a (✔) in the appropriate column alongside each statement.

No.	**Statement**	**Strongly Agree**	**Mildly Agree**	**Mildly Disagree**	**Strongly Disagree**
A.	The handrail was easy to find				
B.	The first step of each flight was easy to find				
C.	Each step was easy to locate				
D.	The last step in each flight was easy to locate				
E.	The stairs were too steep				
F.	The steps were too small				
G.	There were too many flights of steps to cope with				
H.	You suffered some discomfort or soreness in your lower legs				

I.	You felt dizzy and could have fallen				
J.	You were out of breath				
K.	You suffered some discomfort in your chest				
L.	You had some pain in your knees				
M.	You were generally tired				

Q19 Did you feel comfortable going down the stairs? *Circle as appropriate*

Yes No

Q20 If you answered 'No' to Q.19 please comment in the space provided below:

…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
…………………………………………………………………………………………
……………………………………………………………………

SECTION THREE – YOUR LEVEL OF FITNESS

READ: You will be asked in this section about the time you spent being active in the last 7 days before the evacuation. Please answer each question even if you do not consider yourself to be an active person. Think about the activities you do at work, as part of house work and work in the garden, to get from place to place and in your spare time for recreation, exercise or sport.

READ: Now think about all the *vigorous* activities which take *hard physical effort* that you did in the last 7 days before the evacuation. Vigorous activities make breathe much harder than normal and may include heavy lifting, digging, aerobics or fast bicycling. Think only about those activities that you did for at least 10 minutes at a time.

Q.21 During the last 7 days, on how many days did you do vigorous physical activities?

(a) No. of days – Insert number of days ( )

(b) Don't Know/ Not Sure – Tick between brackets if (b) is your answer ( )

(c) Refuse to answer - Tick between brackets if (c) is your answer ( )

If you answered (b) or (c) then please proceed to question 23.

Q.22a How much time did you usually spend on one of these days doing vigorous physical activities?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q22b How much time in total would you spend over the last 7 days before the evacuation doing vigorous physical activities?

(a) Hours per week – Insert the number of hours ( )

(b) Minutes per week – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

READ: Now think about activities which take *moderate physical effort* that you did in the last 7 days before the evacuation. Moderate physical activities make you breathe somewhat harder than normal and may include carrying light loads, bicycling at a regular pace, or playing doubles in tennis. Do not include walking. Again think only about those physical activities that you did for at least 10 minutes at a time.

Q23 During the last 7 days before the evacuation, on how many days did you do moderate physical activities?

(a) No. of days – Insert number of days ( )

(b) Don’t Know/ Not Sure – Tick between brackets if (b) is your answer ( )

(c) Refuse to answer - Tick between brackets if (c) is your answer ( )

If you answered (b) or (c) then please proceed to question 25.

Q24a. How much time did you spend usually spend on one of those days doing moderate physical activities?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don’t Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q24b What is the total amount of time you spent over the last 7 days before the evacuation doing moderate physical activities?

(a) Hours per week – Insert the number of hours ( )

(b) Minutes per week – Insert the number of minutes ( )

(c) Don’t Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

READ: Now think about the time you spent walking in the last 7 days before the evacuation. This includes at home, at work, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise or leisure.

Q25 During the last 7 days before the evacuation, on how many days did you walk for at least 10 minutes at a time?

(a) No. of days – Insert number of days ( )

(b) Don't Know/ Not Sure – Tick between brackets if (b) is your answer ( )

(c) Refuse to answer - Tick between brackets if (c) is your answer ( )

If you answered (b) or (c) then please proceed to question 27.

Q26a. How much time did you spend usually spend walking on one of those days?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don't Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q26b What is the total amount of time you spent walking over the last 7 days before the evacuation?

(a) Hours per week – Insert the number of hours ( )

(b) Minutes per week – Insert the number of minutes ( )

(c) Don’t Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

READ: Now think about the time you spent sitting on week days during the last 7 days before the evacuation. Include the time spent at work, while doing course work or studying, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television.

Q27. During the last 7 days before the evacuation how much time did you usually spend sitting on a weekday?

(a) Hours per day – Insert the number of hours ( )

(b) Minutes per day – Insert the number of minutes ( )

(c) Don’t Know/ Not Sure – Tick between brackets ( )

(d) Refuse to answer - Tick between brackets ( )

Q28. What is the total amount of time you spent sitting or lying down last Wednesday before the evacuation?

(a) Hours on Wednesday – Insert the number of hours ( )

(b) Minutes on Wednesday – Insert the number of minutes (   )

(c) Don't Know/ Not Sure – Tick between brackets (   )

(d) Refuse to answer - Tick between brackets (   )

A3.5 INSTRUMENTS USED TO INFORM AND OBTAIN APPROVAL FOR THE CONDUCT OF A TRIAL EVACUATION

A3.5.1 Request for Assistance

REQUEST FOR ASSISTANCE

FOR OBTAINING AGREEMENT FROM THE OWNER OF M2

INTERNATIONAL RESEARCH PROJECT ON HIGH RISE OFFICE EVACUATION

1. BACKGROUND

Hamish MacLennan is well established as an international expert on the safe evacuation of people from high rise office buildings. At present at the age of 62 years he is in conjunction with xxx conducting research into the actual ability of **all** office workers to safely use the stairs to evacuate and the risk posed to their health and safety in doing so. This research will hopefully lead to a PhD in Inclusive Design at the University of Salford where his supervisor is Professor Marcus Ormerod. The research requires a comparison of the impact of culture as well as all the other parameters. The programme is shown in Section 2 and the activity requiring your assistance is activity 2 which is an international case study involving the observation and measurement of human behaviour and performance in the evacuation of office buildings in New Zealand, Australia, Hong Kong, United Kingdom and Dubai (UAE). It is therefore vital that we secure permission to use your building being over YY storeys in height with a minimum of two stairs as a case study.

2. WHAT ARE WE ASKING THE OWNER AND THE TENANTS TO ALLOW US TO DO?

Office buildings such as your building no doubt will undertake a number of trial evacuations every year for the purposes of health and safety training and emergency preparedness. Each building would have its own set of emergency evacuation procedures and a plan. We would not alter this procedure in any way. All we ask is permission is to do the following:

- Erect small video cameras on every second storey to record the distribution, behaviour and rate of descent of people on the stairs.
- These cameras also record the pattern of entry through the stair entry doors.
- Questionnaires are handed out at the final exit at ground level from each stair. The questionnaires are only four pages long and can be completed (purely voluntary) in less than 10 minutes. These questionnaires would then be given to the floor warden for each storey and collected by a member of the research team.
- The data captured by the cameras and from the questionnaires is then analysed and the evacuation reconstructed as required.

The research team (MacLennan) will sign a document the wording of which is agreed with the Owner and/or Agent (Facility Manager) that undertakes to protect the privacy and rights of the people such that their images from the cameras will never under any circumstances be published in any Report or other document. This is in line with the Ethics Procedures of the University of Salford. We also attach an explanatory memorandum to the Questionnaires as per the attached example.

A copy of the questionnaire is attached. The results of the evacuation will be published in a journal article a draft of which will be sent to the Owner/ Agent for approval and/or modification.

4. CONCLUSION

Your assistance in this matter is greatly appreciated and we advise that we need to move forward quite quickly as discussed at our initial meeting

Hamish MacLennan

Appropriately dated

A3.5.2 Informing Participants/Tenants (Specimen Only) for PDSA Cycles 2 and 3.

Memorandum to Occupants

Date: YYYY/2008

To: Stair Users and Questionnaire Respondents

From: The Research Team

RE: **TRIAL EVACUATION STUDY AT BUILDING ABC – Date of proposed trial evacuation.**

This is just your normal trial evacuation that you are required to participate in every six months. The difference this time is that it has been included as part of an international research project on the use of stairs in evacuation.

Trial evacuations are being monitored in a number of countries. This involves the handing and out and voluntary completion of a questionnaire which asks certain questions that are vital to the study. The monitoring of each evacuation also involves the gathering of visual information about the pattern and speed of your movement down the stairs. This information will be recorded on miniature video cameras positioned in the stairs which are only capable of catching outline images. None of these images will ever be published or used in reports and an undertaking has been given to the building owners to this effect.

The Managers of your building support this research.

The research is being carried out by a Research Team at one of the UK's leading Universities, University of Salford, in Inclusive Design. The researcher, Hamish MacLennan, was formerly Associate Professor of Building Studies at University of Technology, Sydney. Hamish has now retired and is now completing his PhD at the University of Salford. Two well known fire engineering consulting firms are assisting Hamish in the programme.

We would really appreciate your help in this project in order to provide top value for each one of you and to increase your sense of safety in the building and its emergency systems. The outcomes will also be vital in helping those building occupants who are not really capable of using the stairs establish another acceptable and safe way of evacuating the Building.

What will happen?

You will have followed your normal procedures. The questionnaires would have been handed to you at the final exit from the stairs to the outside of the building. We would really appreciate about 10 minutes of your time whilst everything is still fresh in your mind to complete the questionnaire. When you have completed it please hand it back in the envelope provided to your Floor Warden. Please note that the completion of the questionnaire is purely voluntary.

Thank you very much for your help.

Kind Regards

Hamish MacLennan

Researcher

University of Salford and Atkins ME

Appropriately dated

A3.5.3 Actual Agreement (Specimen Only)

SURVEYS, FILMING, VIDEOTAPE AND/OR PHOTOGRAPHY DECLARATION FORM (NON COMMERCIAL)

I Hamish Alistair MacLennan, a full time PhD research student at the University of Salford, formally seek permission to survey, film, videotape or photograph any part of the station for the purposes of a university PhD research project into the ability of people to safely use stairs for the evacuation of high rise office buildings for which I will receive no commercial gain now or at any time in the future.

The parts of the office building selected and approved by ***Building Owner/ Facility Manager XXX*** *for the observation and capturing of visual data will be the fire stairs leading down to the ground floor and to the outside of the building. The videotaping is for the* ***sole*** *purpose of recording and analysis of data on the movement of people on stairs. Hamish MacLennan and indeed the University of Salford hereby undertake that the videotaped data so recorded and analysed will never be presented in written, electronic or verbal format in any Report, Dissertation, Journal, Presentation or any Article and the like in the Public Domain.*

I agree to abide by the instructions of those provided to me when signing in on the day of the evacuation.

Name .Hamish MacLennan

Signature

Address: SURFACE, School of the Built Environment, The University of Salford,

Level 4, Maxwell Building,

The Crescent, Salford,

Manchester, M5 4WT Date . To be completed

Copy of Ethics Approval etc from University of Salford attached etc.

For Building Owner purposes only (This form must be returned to the Building Owner's Representative

Building Owner Reference...

Approved on behalf of Building Owner

Name...

Job Title ....

Signature...

Date...

Approved by Researcher

Hamish MacLennan Agreement etc.

A3.6 2008-2010 TRIAL EVACUATION STUDY PDSA 1-3 OBSERVER PROCEDURES AND CHECK LIST

Observer Name:

Evacuating from Floor:

Using the _________ stairway.

Number on Recorder:

Preamble:
Because of the transitory nature of the events being observed and large size of a high rise office building and its population it is essential that the observers be a part of a well organised team. As a member of this team each one of you is being requested to record observations at some assigned position or sequence of positions in the building.

Your observations will be used to examine, in detail, localised events at your assigned positions. Furthermore your observations, recorded on your Dictaphones, will form part of the re-construction of the whole evacuation exercise.

The following procedures relate primarily to the collection of data about the movement of people during the exercise. Please use your experience and judgement to conduct other observations which will assist in an objective evaluation of this particular exercise.

Detailed Procedure:
(Note that a checklist permitting a rapid review of these procedures is provided at the end of this document)

The immediate goal of your observations is to make a recording containing as much information as you can collect about the events and conditions around you in the stairs. Using a Dictaphone set to record continuously, you need not be concerned with watching a clock and noting times for various events. As long as your recording includes some reference signal such as the evacuation alarm and at the end of the evacuation such as “final exit door” then it is a straightforward task to draw up a detailed spread sheet of your observations on a time scale. The log can be related to observations made by other observers at the same time. The analysis of your recording will be done for you leaving you with only the challenge of rapidly observing and reporting on the following conditions and events;

5. Occupant behaviour to the evacuation alarm signals.
6. The flow of occupants into your assigned stair.
7. Your own movement down the stairs with the occupants of your assigned floor noting each landing as you step on to it and also any delays or slowing down of the rate of descent.
8. The density of population in your immediate vicinity in the stairs and their distribution patterns (e.g. side by side. Single file etc.).

As you will note from this list, you are apparently requested to report on several things simultaneously. To make your observations challenging rather than impossible, the following detailed procedures are suggested:

(o) Prior to the exercise, record your name, assigned floor, and assigned exit on the Dictaphone on side A of the cassette. Also check the number on the back of the cassette or write your assigned floor and exit number on the back if there is no number.

(p) Go up to your assigned floor about five minutes before the alarm is due to be sounded before the start of the exercise. Ideally you should wait with the main fire warden for your assigned floor until the drill starts. Before and during the drill, try to conduct your observations so that the activities of those around you are not interrupted.

(q) Prior to the alarm sounding, remembering that you are required to switch on the recorder five minutes before the start, record the time on your watch as a starting reference time.

(r) Once your Dictaphone has been switched on do not turn it off until you are outside the building.

(s) Move to the floor area next to your assigned exit. Make sure that the tape recorder is picking up all the background sounds and any comments you wish to make about how the people respond to the alarm.

(t) When your floor is due to be cleared take a count of the people as they go through the doorway into the assigned stair. In this case instead of counting “one, two, three etc.” a simple “Q” should be recorded every time a woman crosses and “P” for a male. This permits an accurate determination of the rate of flow into the exit and also assists in describing the gender mix of your floor.

(u) Try to be one of the last persons to leave your assigned floor by your assigned stair. Enter the stair as part of the last group so that you do not become separated from them. Also state approximately how many people will be behind you.

(v) As you down the stairs please record the floor number of every floor as you reach the landing. This is needed so that we can plot your progress down the stairs and estimate your descent speed.

(w) When going down the stairs, note at the lower floors, if people from these floors are entering the stairs before your group reaches them. Note any delay or congestion that this may be causing due to mixing.

(x) Note how people go down the stairs relative to each other e.g. side by side, single file, staggered formation a few steps apart etc. Try and keep yourself in the same pattern as the others with the same space in between.

(y) At each storey take a count of the number of people who occupy the area of one flight and one landing in front of you and record the number on the Dictaphone e.g. seven in front. Follow this by the number using the handrail e.g. four on rail. This means that out of the seven people in front of you only four are using the handrail.

(z) Whenever your speed changes noticeably indicate this on the recording.

(aa) When you arrive at the bottom of the stairwell you will see the final exit and camera. Look up at the camera and clearly state your floor number. The camera will record this and the times can then be correlated between the camera and your recording.

(bb) Also proceed to well outside the building before you turn the recorder off. Do not forget to record your final reference time before you do so.

2008-2010 TRIAL EVACUATION STUDY

OBSERVATION CHECK LIST for PDSA 1-3

Observer: ________ Floor: ______ Exit: ______ Recorder No.:__

(Items marked with an asterisk are of high priority)

(a) * Record name, floor and exit on recorder before drill.

(b) * Meet with observation team in the ground floor lobby fifteen minutes before the start of the exercise and synchronise your watch with the rest of the team.

(c) * Go to your assigned floor five minutes before the drill is due to start.

(d) * Switch on your DICTAPHONE when you reach the floor.

(e) * Record the time on your watch to the nearest second.

(f) * Leave your DICTAPHONE running until you are well outside the building.

(g) * Note what happens in the vicinity of your exit.

(h) * Record a count of the people on your floor as they cross into the exit stair ("Q" for females and "P" for males).

(i) * Be one of the last to leave your floor but leave in the last "group".

(j) * Record the number of each floor level as you step on to the landing at each level.

(k) * Note people entering the stairs as you descend.

(l) * Note how many people are in front of you on the flight and how many are holding the handrail.

(m) * Note how the people in front of you are spaced on the stairway.

(n) * Note any changes in your rate of descent.

(o) * Look up at the last camera before the final exit and clearly state your floor number.

(p)* Move well clear of the building and provide a reference time before turning off the recorder. Make any other observations that are relevant.

.

Stair Descent Chart

A3.6.1 Occupants and Symbols – Stair Descent Chart

There are symbols on the stair descent graphs to aid interpretation. Occupants who looked like they struggled on the stairs, or were overtaken, or held people up are coded by the characteristics of age, weight, type of shoe, and whether or not they used the handrail.

Most occupants' symbols only appear on two data points; drawing attention to their area of relevance. Symbols down the length of a data series indicate that the occupant had difficulties during the majority of their stair descent.

Pink-edged = occupant was overtaken by a few people

Blue-edged = occupant was significantly overtaken. They probably rested off camera

Orange-edged = occupant rested or paused on camera

Green-edged = occupant held people up

Black-edged = occupant stumbles

White-edged = occupant has/might have some health issue

Yellow-edged = occupant deserves additional comment. See section below

Slim = BMI< 25 Overweight = BMI > 25 < 30 and Obese = 30+

SYMBOLS:

Female:

60 years +

X slim, business shoes, no handrail

X slim, business shoes, handrail

X overweight, business shoes, no handrail

X overweight, business shoes, handrail

35 – 59 years

slim, high heels, handrail.

slim, flat sandals, handrail

slim, sports shoes, no handrail

slim, sports shoes, handrail

slim, business shoes, no handrail

slim, business shoes, handrail

overweight, slight heel, no handrail

overweight, slight heel, handrail

overweight, business shoes, no handrail

overweight, business shoes, handrail

overweight, sports shoes, no handrail

overweight, sports shoes, handrail

overweight, flat sandals, handrail

overweight, high heels, handrail

obese, sports shoes, no handrail

obese, sports shoes, handrail

obese, flat sandals, handrail

obese, business shoes, handrail

obese, business shoes, no handrail

vision impaired

Less than 35 years

slim, sports shoes, used handrail

slim, sports shoes, no handrail

slim, slight heel, handrail

slim, slight heel, no handrail

- slim, business shoes, handrail
- slim, business shoes, no handrail
- Young, slim, sandals, no handrail
- overweight, business shoes, handrail
- overweight, business shoes, no handrail
- overweight, sports shoes, handrail
- overweight, sports shoes, no handrail
- overweight, slight heel, no handrail
- slim, high heels, handrail
- slim, heels, no handrail
- slim, flat shoes, no handrail
- obese, high heels, handrail

Male:

60 years +

- overweight, business shoes, no handrail
- overweight, business shoes, handrail
- overweight, sports shoes, handrail

35 – 59 years

- slim, business shoes, no handrail
- slim, business shoes, handrail
- overweight, business shoes, no handrail
- overweight, business shoes, handrail
- overweight, sports shoes, handrail
- overweight, sports shoes, no handrail
- slim, sports shoes, no handrail

- slim, sports shoes, handrail

Less than 35 years

- slim, business shoes, no/light handrail
- slim, business shoes, handrail
- slim, flat/sports shoes, handrail
- slim, sports shoes, no handrail

A3.6.2 Occupants needing additional comment

Christchurch Trial Evacuation: This occupant is obese and carries a large number of bags. She takes a while to get out of the doorway at level 6, but keeps up with the flow of occupants evacuating the building. She is descending Stair A.

Unisys East Stair and IPAQ survey: This man dropped back to talk with friends from his own floor. He is not having difficulties.

Unisys East Stair and IPAQ survey: This man was interested in writing on the piece of paper in his hand. He would rush ahead and then try to write on landings. He had arguments with a warden, who wanted him to evacuate with everyone else.

Kent Tower, stair 2, chart 3 and IPAQ Survey: This female person and her friend (less than 35 years old, slim, not using the handrail) must have rested on a landing out of sight of a camera; they also rested on level 6. She appears to be having difficulty and health condition not known.

This person is carrying a stroller and could well be impeding his own view of the stairs. Manchester Clean Stair.

A3.7.3 Observers' Comments

Observer comments are generally recorded on separate spread sheets because of lack of space on stair descent charts. These comments will apply during triangulation. The Kent Street stair descent charts do, however have observers'comments on them. The observers followed a group of occupants down the stairs and recorded how many occupants there were on the stair in front of them and how many of those occupants were using the handrail. The observers' descents are marked in red.

Observers' comment: occupants on stairs	1
	2
	3
	4
	5
	6
	10
Observer's comment: occupants using rail	0
	1
	2
	3
	4
	5
	6

Note: *Other observer comments are presented after triangulation study extrapolated from the observer spread sheets. Also note that as number of handrail users increase in descent this was observed to mean that the occupants were tiring or worried about their stability.*

A3.8 SPECIMEN STAIR ENVIRONMENT ASSESSMENT TEMPLATE

The specimen template may be found on the next three pages and presents the results for one stairwell.

Assessment scales are also used here suitable for factor analysis as a means of reducing the data.

UNIVERSITY OF SALFORD

SCHOOL OF THE BUILT ENVIRONMENT

PHD PROGRAMME

‘THE SAFE DESCENT OF MULTIPLE FLIGHTS OF STAIRS IN MULTI STOREY OFFICE BUILDINGS; A USER BASED CAPABILITY STUDY’

STAIR ASSESSMENT TOOLKIT

Hamish A. MacLennan
Researcher
SURFACE Inclusive Design Research Centre

BUILDING ID: Exploratory Case Study *Building 7*	STAIR NUMBER 2	NO. STOREYS 20

Variable ID	Variable Description	Rating Scale	Actual Rating	Comments
Storeyno	Number of storeys	Number	*20*	Convert into height ultimately
Turnsno	Number of turns	-2 to +2	*-1*	-2 : 4 or more turns with irregular flights/storey -1 : 3 turns with uneven flights/ storey 0 : Traditional dog leg stair with uneven flights/storey – 2 turns +1 traditional dog leg with even flights / 2 turns +2 scissor type with intermediate landing and 1 turn
Treadsize	Width of treads as per Roys Study	Number	*250*	Statement of actual width
Treadsafe	Tread width and stance	-2 to +2	*-2*	-2: < 250 -1: >250-<280 0 : 280 – 300 +1: 300- 320 +2: 320 - 350
Riserht	Riser height	Number	*190*	Statement of actual height
Risercom	Riser comfort (measure of impact on pain/ shock absorption, stability and overall confidence)	-2 to +2	*-2*	-2: >190 -1: >170-<190 0 : 160-<170 +1: >150-<160 +2: 130-150
Stairsteep	Stair pitch in %age terms – riser/tread as an expression of stair geometry	Percentage	*79*	Statement of actual pitch but not in degrees
Strsteepcon	Measure of stair steepness and user confidence	-2 to +2	*-2*	

Variable ID	Variable Description	Rating Scale		Comments
Stairuniform	Uniformity of risers and tread width/ profile and includes irregularities due to wear, cracking, and set out.	-2 to +2	*0*	-2: Greater than 10mm in first and last three risers in each flight -1: >5 and <10 or where riser in first and last three risers in each flight >10mm or marked wear pattern 0 : 5mm (ave) in each flight (NFPA) +1: 0-5mm +2: completely uniform and in pristine condition
Clearwyd	Clear width of path	mm	*1020*	Clear width of flight measured between handrails or handrail and wall. Used with no. of handrails for handrail efficacy.
Hdrlprovide	No of handrails per path	Number	*1*	Used in conjunction with Clearwyd for handrail efficacy.
Hdrlefficacy	Handrail efficacy	-2 to +2	*-1*	-2: no rail available or where only one rail is provided and where the reach is >750mm. -1: where one rail is provided and it is within 750mm of user 0: where two rails are provided along the edge of the path and clear width does not exceed 2000mm +1: where two rails are provided and clear width of path is less 1500 +2: where two rails are provided and clear width is <1500
Hdrldia	Handrail diameter	mm	*35sq*	Diameter of handrail in mm
Hdrlgrasp	Handrail graspability	-2 to +2	*-1*	+2: 60mm diameter plus and/or where posts break grasp +1: >50<60 diameter and/or where posts break grasp below 270^0 power grip other than BCA Guideline 0 : 40-50 with continuous grasp with concession for BCA Guideline +1: 38 – 40mm but with continuous 270^0 power grip +2: 32-37mm with continuous 270^0 power grip

Variable ID	Variable Description	Rating Scale		Comments
Illuminat	Level of illumination	lux	*<50*	
Illumconf	Level of illumination to feel confident	-2 to +2	*-2*	
Stairleg	Step legibility	-2 to +2	*-2*	
Hdrlleg	Handrail legibility	-2 to +2	*+1*	
Contrast	Clarity of environment and colour	-2 to +2	*-1*	
Nosingcon	Sharpness of nosing	-2 to +2	*0*	
Doorencroach	Encroachment of exit door	-2 to +2	*+2*	
Obstruct	Structural or services obstruction locally within path	-2 to +2	*+2*	
Comfort	Degree of comfort	-2 to +2	*-1*	
Wellvert	Width of well/ openness of stairwell	-2 to +2	*-2*	
Orientate	Degree of orientation	-2 to -2	*+1*	
Fallheight	Falling height longest flight	mm	*1520*	
Slipres	Slip Resistance	-2 to +2	*+1*	
Familiar	Frequency of use	-2 to +2	*-1*	
Management	Maintenance, evac. organisation etc. etc.	-2 to +2	*0*	
Rest	Space on landings for people to rest	-2 to +2	*+1*	

Note: Variable row highlighted in blue is where the actual measurements are used. The yellow highlight is where the various elements are rated on a scale that is suitable for factor analysis.

A3.9 FOCUS GROUPS WITH TRIAL EVACUATION EXPERIENCE AND FUNCTIONAL LIMITATIONS (RESULTS)

A3.9.1 Fuller Figure Focus Group – Summary of Free Discussions

Refer to Ishikawa Chart Summary

QUESTION 1 – HOW DO WE KNOW THAT THE SITUATION IS AN EMERGENCY OR NOT? *(required to "start free discussion" – does not imply that Mature Age Focus Group followed this prompt)*

Answer 1

'You will be told whether it is an emergency or a trial!'

Answer 2

'Up the road (i.e. in their other building) people can use the stairs for access between floors so that at any time there could be a number of people in the stairs in any case, so you might not know! You would still hear the alarms anyway!'

Answer 3

'Nine times out of ten with the procedures that you have in place here – people would know' – comment made by facilitator covering multiple discussion after Answer 2.

Answer 4

NOTE: The discussion digressed to stair design resulting from people's observations:

- I would have expected that the stairs in this newer building (i.e. 275 Kent Street) would have been wider along with the steps compared to the other older building in Martin Place. (*This triangulates well with observations of respondents to the NY Times Blog, those of Andrea Galyean, A Graduate Journalism Student from the John Jay College at NYU on 2 May 2008 in an article entitled "Tall Buildings, Skinny Stairs", http://skyscraperproject.blogspot.com/2008/05/tall-buildings-skinny-stairs-in.html*)

- We use the other stairs in this building which are much better as they accessible and much more comfortable. They connect all the floors but are not continuous. Every fourth level they separate so that you have to walk from one stair to the next. They cannot be used in a fire as they are physically separated on every fourth level – part of the original fire engineering design.

- Looked at the lift size coming up where there was a notice that 24 people could fit in but I am fairly certain that you would only fit 12. People have increased in size.......(this triangulates once again with Andrea Galyean's comments (2008))

- "What determines the width of the fire stairs?" Others answered – "Two people walking side by side (each measuring 22") which was called two egress units. Each egress unit was 550mm originally but that has now shrunk to 500mm as a result of metrification."(Interesting to note that the 1968 Codes in New York were less restrictive than the former Codes. Number of stairs for buildings of 10 storeys and above were reduced by some 50% and the width between walls was 2 units of 22" which is 44"- (Jonathan Starkey on comments made by Glenn Corbett of the John Jay College of Criminal Justice in Manhattan published in an article entitled "Clash of Past, Present and Future Offers Context", Skyscraper Project, on 3 May 2008, *http://skyscraperproject.blogspot.com/2008/05/clash-of-past-present-and-future-offers-in.html)* which allowing 100mm for handrails (single) results in a clear width of 1016mm which is similar to the current clear width in the Building Code of Australia and also the Acceptable Solution C/AS1 under the NZ Building Code. The overall width in NZ and Australia is still also directly dependent on the number of occupants where they exceed 100 persons. The formulas are slightly different.)

QUESTION TWO: BASED ON EXPERIENCES WITH FIRE STAIRS CAN YOU COME UP WITH ANY ALTERNATIVES FOR EVACUATION:

Answers

- The flights should be longer so as to have fewer turns

- Contrasting colours – improve legibility of steps, placement of handrails, signage for levels, etc. to avoid whiteout etc.

- Stairs should be wider

- Large numbers on each of the floors so that you know where you are

- Passing landing every two or three floors with enough space for those who needed to take a rest.

- Greater headroom for taller people. Two of the group felt uncomfortable with a clear height of 2030mm. Have some people in our building over 7 foot tall.

- Level of lighting can be enhanced
- Sound absorbing surface – very noisy with people talking and sound from MV fans.
- Following the WTC there is a heightened awareness of what can happen in a fire which could increase the levels of stress and anxiety. (triangulates well with statements in a recount of survivors' comments and telephone conversation records of victims entitled "102 Minutes" (Dwyer and Flynn 2005)

QUESTION 3: IS THERE ANOTHER WAY OF DOING IT? Answered via general discussion and further questions which are expanded via Discussions 1-3:

1st Discussion: Direct to Question 3:

- Could we use the central stairs?
- No the central stairs are blocked off every 4th floor in a file by fire shutters which come down.
- That does not mean that we could not use them in an emergency other than fire.
- If there is a bomb evacuation then we could use them.
- Alternative solution from the Fire Engineer

2nd Discussion – "what if we can't use the stairs" - modifying Q3:

- Elevator evacuation?
- No problem using the elevators even using in event of fire if designed for it. Power would need to be assured.
- What about MGM Fire shafts acted as a chimney?
- We should be promoting the use of other means in our training?

3rd Discussion – "if there are other ways then should we be practicing them and would it mean that we have too many different choices?" – further modifying Q3

- One procedure for each
- Multiple triggers – few standardized responses??
- Yes it must be kept simple.

- Should be looking at blow up slides – used in Aeroplanes – there no practices by passengers but staff are familiar so that staff tell you what to do. So you do what you are told to do?? Queensland allows training of staff and not all.
- Problem with this approach! One warden in the last trial evacuation ordered a heavily pregnant woman to tackle 19 storeys worth of stairs!
- Must therefore have the right response. Must train for what we have to do.
- Those people with special needs must be part of that training routine.
- If evacuating then people with needs do what they have to do and must rehearse it.

CLOSE

A3-9.2 Mature Age Focus Group – Summary of Free Discussions

Refer to Ishikawa Chart Summary

(Free Discussion started straightaway so comments follow from a general discussion)

First Person generally

- Sore knees so it's not always easy
- I wear glasses which I have to take off when I go down the stairs. Edge delineation is therefore very important
- Step size is very narrow – this worries me. Also the tightness of the stairs and the number of turns I have to make.
- Grey after grey makes it extremely monotonous.
- Crowds in the stair worry me especially if someone were to fall.
- The air in the stair when it is full of people make it very uncomfortable

Next person

- I am on floor 26. I do not believe that I could keep up the same pace all the way down.

Would you then use the handrail more and more?

- No I would most likely use the handrail anyway.
- Twisting action on the stairs has an effect on me
- Slow movers would create congestion and I would most likely be one of them after going down a few storeys.
- Merging makes it disruptive on the stairs
- Temperature is a crucial issue e.g. it was 45^0C in Adelaide today.
- Walking behind people in thongs (flip-flops) was annoying as one could step on the loose thong causing the wearer to trip. (Other person adds comment) That would cause others to take a 'dive'.
- I have a very sore knee that causes me problems
- Too many in front – makes me think I am going to fall.

Next person

- I am extremely scared of falling
- I will therefore hold on the handrail for grim death. As long as I can do this then I feel alright.
- What is the situation concerning lighting? If they were off this would be a major concern to me and slow me right down.

Next person

- Very repetitive – legs become very sore. Could be a major problem after about 15 floors. This is especially so seeing our lifestyle has become increasingly sedentary.

Facilitator Comments about reduced vision and prompts further general discussion about other stair design issues

Next Person

- Glasses issue in not being able to see where one is placing one's foot is an issue and therefore increases the risk of falling.
- Repetition the constant rotation makes me bored disorientates me and makes me dizzy.
- Having to change direction or climbing disorientates me.
- Constant gossiping in groups slow us down.
- Trials appear to do away with the urgency of a real life event.

Next Person

- Multi focal glasses change in brightness with lighting so that illumination of treads and risers changes so that this affects placement of feet and one's confidence.
- Use handrails because of balance problems – i.e. to maintain balance.
- Other person comments, "Further down you go the worse the balance problem gets."
- Gives you the extra ability to pull up when you use the handrail.
- I hold on to handrail for support to take the weight off my knees because of my arthritis.

Question – What would we do to improve things if given a free hand?

- Handrails on both sides
- Less turns on stairs
- Use better internal stairs – likes the disconnection every three floors
- Marking on each step edge so that we can see them more clearly
- Should not change descent to ascent within the system as this become disorientating.
- Mark large numbers of floors on each level
- Floors where entry doors are missing can also disorientate

Facilitator question – Is there any other alternative to the stairs for those who are slow movers etc?

- Yes we already have the use of the emergency/ goods lift for mobility impaired
- Don't they say that lifts should not be used in event of fire?
- Normally we don't let people use lifts except for mobility impaired who can use the proper emergency lifts with the assistance of the Fire Brigade.

- Company is employing more and more people with special needs because of Equal Rights so what do we do?
- Have we had any actual accidents? Have we done any surveys on using the lifts?
- Answer is “No we have not”.
- Problem is that we are apathetic in terms of trial evacuations so that many people rush to the lifts because they are closed down to get out of doing the evacuation.
- PEEPS is mentioned about – We should adopt this approach is a comment that comes back.
- The problem of using lifts in a trial evacuation is one of liability.
- All of these things need to be thought about.
- Suggestion of blow up plastic slides – no I don’t think we would relish that – Escape chute was then discussed and some commented favourably but agreed that it would take some time for it to be accepted. Also liability problem. Example of 87 year old lady using chute and accessing it on her own out of here wheelchair.
- Internal accessible stairs were mentioned again for non fire related emergencies. Shutters could be arranged to channel people down the stairs. These stairs are ones that people that are used to using.

CLOSE

APPENDIX A4

A4.1 CASE STUDY PARTICULARS - PHOTOGRAPHS

A4.1.1 Brisbane Building 3

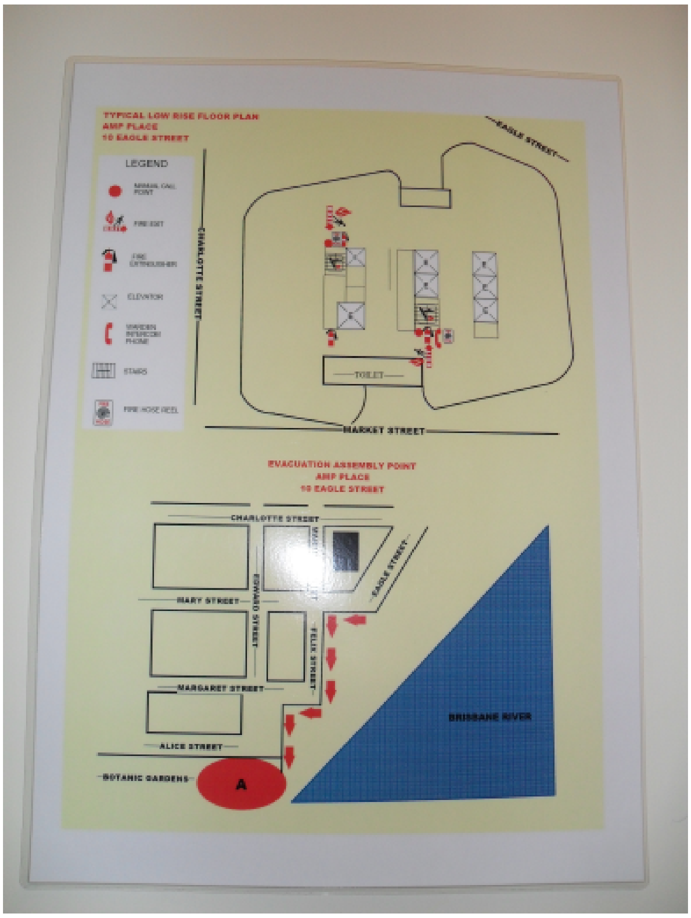


Fig.B3, 1 - Evacuation Procedures and typical floor plan

Fig.B3, 2 - Exit access door signage – cluttered

Fig.B3, 3 - Door handle detail

Fig.B3, 4- Typical flight looking down from stair entry point

Fig.B3, 5 -Looking up flight to intermediate landing

Fig.B3, 6 Looking down flight from intermediate landing to entry door - floor signage not visible

Fig.B3, 7 - Looking across from the intermediate landing to see floor number and hydrant valve

Fig.B3, 8 - Looking up flight from intermediate landing to floor number sign and hydrant valve

Fig.B3, 9 - Detail of typical steps showing patching

Fig.B3, 10 - Handrail detail

A.4.1.2 Brisbane Building 7

Figure B7.1 - Building 7 Evacuation Procedures Notice and Typical Floor Plan; displayed in lift lobby

Figure B7.2 - Stair looking up from main landing on Level 10. Note contrasting handrails and emergency lighting on intermediate landing

Figure B7.3 - Typical down flight directly in front of exit door,

Figure B7.4 - Looking up the down flight towards exit access door

Figure B7.5 - View of two intermediate risers - 4 turns per storey

Figure B7.6 - View down typical flight from intermediate landing towards recessed exit access door

Figure B7.8 - Outline of 'grey' steps against white/ cream wall - note absence of handrail

Figure B7.9 - View of well formed between flights (vertigo trigger)

Figure B7.10 - Stair 1 entry door - no contrast for stair number sign above stainless steel warning sign

Figure B7-11As per FigureB7.10 except stair 2

A4.2 REVISITED BUILDINGS 3 AND 7 FOR EXPLORATORY CASE STUDY – STAIR ENVIRONMENT INPUT DATA

Building revisited were Building 3 (34 storey in Brisbane) and Building 7 (20 storey in Brisbane)

Refer to Appendix A3-6 for actual physical assessment template and explanation of rating scale changed from -2>+2 to 1-5 with 1= worst condition and 5 = best condition for purpose of factor analysis.

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
Ex3.1	34	4	260	2	185	2	75	2	2	1020
Ex3.2	34	4	260	2	185	2	75	2	2	1020
Ex8.1	20	2	250	1	190	1	79	1	1	1020
EX8.2	20	2	250	1	190	1	79	1	1	1020

Table – Stair geometry and width

Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
Ex3.1	34	1	2	200*	1
Ex3.2	34	1	2	200*	1
Ex8.1	20	1	2	123*	2
EX8.2	20	1	2	123*	2

Table – Handrails provision for support (* *rectangular section handrail*)

Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
Ex3.1	34	151	4	1	4	3	3
Ex3.2	34	151	4	1	4	3	3
Ex8.1	20	49	1	1	4	2	3
EX8.2	20	49	1	1	4	2	3

Table – Stairway visibility

Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
Ex3.1	34	5	3	3	4	4	1850	4	2	5	4
Ex3.2	34	5	3	3	4	4	1850	4	2	5	4
Ex8.1	20	5	5	5	1	4	1520	4	2	3	4
EX8.2	20	5	5	5	1	4	1520	4	2	3	4

Table – Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

EXPLORATORY CASE STUDY – STAIR ENVIRONMENT INPUT – BUILDINGS 3 AND 7 (cells with neutral highlighting are actual measurements – others are rating scales of 1-5 with 1 being the worst and 5 the best – user ratings)

A4.3 2008 – 2010 CASE STUDY STAIR ENVIRONMENT INPUT DATA

The Buildings included in the 2008 – 2010 Case Study are:

- PDSA Cycle 1 – Buildings M[3]1 = Christchurch and M2 = UAE
- PDSA Cycle 2 – Buildings M4 = Wellington 1 and M3 = Manchester
- PDSA Cycle 3 – Buildings M5 = Wellington 2 and M6 = Sydney

Refer to Appendix A4-6 for actual physical assessment template and explanation of rating scale changed from -2>+2 to 1-5 with 1= worst condition and 5 = best condition for purpose of factor analysis.

[3] M = Main 2008-2010 Case Study

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
m1-1	10	5	280	3	175	2	63	2	1	1020
m1-2	10	5	280	3	175	2	63	2	1	1020
m2-1	36	4	300	4	175	2	58	3	4	1020
m2-2	36	4	300	4	175	2	58	3	4	1020

Table – Stair geometry and width

Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
m1-1	10	2	5	40	4
m1-2	10	2	5	40	4
m2-1	36	5	4	60	2
m2-2	36	5	4	60	2

Table – Handrails provision for support

Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
m1-1	10	50	2	2	4	3	2
m1-2	10	50	2	2	4	3	2
m2-1	36	<100	5	1	1	1	4
m2-2	36	<100	5	1	1	1	4

Table – Stairway visibility

Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
m1-1	10	5	5	3	5	4	2975	4	4	1	4
m1-2	10	5	5	3	5	4	2975	4	4	1	4
m2-1	36	5	5	3	4	1	1750	4	2	1	5
m2-2	36	5	5	3	4	1	1750	4	2	1	4

Table – Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

2008-2010 CASE STUDY – STAIR ENVIRONMENT INPUT – CYCLE 1 – BUILDINGS M1(Christchurch) and M2 (UAE) ***(cells with neutral highlighting are actual measurements – Others are rating scales of 1-5 with 1 being the worst and 5 the best – for user testing)***

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
m3-1	26	5	260	2	150	5	58	3	4	1000
m3-2	26	5	260	2	150	5	58	3	4	1000
m4-1	17	3	247	1	190	2	78	1	3	975
m4-2	17	3	247	1	190	2	78	1	3	960

Table – Stair geometry and width

Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
m3-1	26	2	5	40	4
m3-2	26	2	5	40	4
m4-1(dirty)	17	4	2	126025*	2
m4-2(clean)	17	4	2	126025*	2

Table – Handrails provision for support (**rectangular handrail sections*)

Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
m3-1	26	<100	2	2	4	4	4
m3-2	26	<100	2	2	4	4	4
m4-1(dirty)	17	50	2	2	5	1	4
m4-2(clean)	17	100	3	4	3	3	4

Table – Stairway visibility

Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
m3-1	26	5	5	4	5	4	1650	3	2	4	3
m3-2	26	5	5	4	5	4	1650	3	2	4	3
m4-1(dirty)	17	4	1	2	4	3	1520	2	1	1*	4
m4-2(clean)	17	4	5	3	4	4	1520	5	5	4	5

Table – Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

2008-2010 CASE STUDY – STAIR ENVIRONMENT INPUT – CYCLE 2 – BUILDINGS M3 (Manchester) and M2 (UAE) (cells with neutral highlighting are actual measurements – Others are rating scales of 1-5 with 1 being the worst and 5 the best – for user testing.

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
m5-1	18	1	270	2	170	2	63	2	3	1065
m5-2	18	1	270	2	170	2	63	2	3	1065
m6-1	32	1	260	2	190	2	74	2	5	1000
m6-2	32	1	260	2	190	2	74	2	5	1040
m6-3	32	1	260	2	190	2	74	2	5	1040

Table – Stair geometry and width

Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
m5-1	18	4	1	R	1
m5-2	18	4	1	R	1
m6-1	32	4	2	50	3
m6-2	32	4	2	50	3
m6-3	32	4	2	50	3

Table – Handrails provision for support *(R= irregular rectangular section)*

Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
m5-1	18	100	3	2	2	3	4
m5-2	18	100	3	2	2	3	4
m6-1	32	250+	5	4	2	2	4
m6-2	32	250+	5	4	2	2	4
m6-3	32	250+	5	4	2	2	4

Table – Stairway visibility

Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
m5-1	18	5	5	1	1	3	1050	1	4	5	3
m5-2	18	5	5	1	1	3	1050	1	4	5	3
m6-1	32	1	5	2	1	4	1560	5	2	5	2
m6-2	32	5	5	2	2	4	950	5	2	3	4
m6-3	32	1	5	2	2	4	1560	5	2	3	2

Table – Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

2008-2010 CASE STUDY – CYCLE 3 – Building M5 (Wellington 2) and Building M6 (Sydney) (*cells with neutral highlighting are actual measurements – Others are rating scales of 1-5 with 1 being the worst and 5 the best – for user testing)*

A4.4 2008 – 2010 CASE STUDY: BUILDING M6 EXAMPLE OF CAMERA AND OBSERVER LOCATION SCHEDULES

The following tables provide an example of how the time line was co-ordinated between three stairs with a phased evacuation. The data was gathered directly from the intercommunication panel located in the emergency control room at street level by the author. Time stamps could be cross checked with the observers and also with those on the video cameras as the master time-clock for the building was as advised from ABC Radio. This time stamp was co-ordinated between all the members of the case study team in the ground floor foyer on their watches before switching on the cameras and also prior to the observers switching on their Dictaphones 10 minutes before the designated starting time for the evacuation.

Schedule 1 - Cameras and Observers Stair One

CAMERAS IN STAIRS	LEVEL	CAMERAS AT ENTRY DOOR AND/OR OBSERVER POSITIONS
	Level 32	Panasonic (4GB) D1/32 – Observer
	Level 31	
Panasonic (4GB) 1/30 on first flight	Level 30	
	Level 29	
	Level 28	Panasonic (4GB) D1/28
	Level 27	
Panasonic (4GB) 1/26 on first flight	Level 26	
	Level 25	
	Level 24	Panasonic (4GB) D1/24
	Level 23	
Panasonic (4GB) 1/22 on first flight	Level 22	
	Level 21	
	Level 20	Panasonic (4GB) D1/20
	Level 19	
	Level 18	
Panasonic (4GB) 1/17 on first flight	Level 17	People entering from L 17 will be visible on this camera
	Level 16	
	Level 15	
Panasonic (4GB) 1/14 on first flight	Level 14	People entering from L 14 will be visible on this camera
	Level 13	
	Level 12	
Panasonic (4GB) 1/11 on first flight	Level 11	People entering from L 11 will be visible on this camera
	Level 10	
	Level 9	
	Level 8	
	Level 7	
	Level 6	
CCTV hardwired to Security Rm.	Level 5	DVD burned after Evacuation
CCTV hardwired to Security Rm. monitoring final exit door	Levels 4 – LG final exit	DVD burned after Evacuation

Schedule 2 - Cameras and Observers Stair Two

CAMERAS IN STAIRS	LEVEL	CAMERAS AT ENTRY DOOR AND/OR OBSERVER POSITIONS
	Level 31	Panasonic (4GB) – D2/31 and observer 2 – Michael Bower
	Level 30	
Panasonic (4GB) – 2/29 on first flight	Level 29	
	Level 28	
	Level 27	Panasonic (4GB) – D2/27
	Level 26	
Panasonic (4GB) – 2/25 on first flight	Level 25	
	Level 24	
	Level 23	Panasonic (4GB) – D2/23
	Level 22	
Panasonic (4GB) – 2/21 on first flight	Level 21	People entering from L 21 will be visible on this camera
	Level 20	
	Level 19	
Panasonic (4GB) – 2/18 on first flight	Level 18	People entering from L 18 will be visible on this camera
	Level 17	
	Level 16	
Panasonic (4GB) – 2/15 on first flight	Level 15	People entering from L 15 will be visible on this camera
	Level 14	
	Level 13	
Panasonic (4GB) – 2/12 on first flight	Level 12	People entering from L 12 will be visible on this camera
	Level 11	
	Level 10	
	Level 9	
	Level 8	
	Level 7	
	Level 6	
CCTV hardwired to Security Rm.	Level 5	DVD burned after Evacuation
CCTV hardwired to Security Rm. monitoring final exit door	Levels 4 – LG final exit	DVD burned after Evacuation

Schedule 3 - Cameras and Observers Stair Three

CAMERAS IN STAIRS	LEVEL	CAMERAS AT ENTRY DOOR AND/OR OBSERVER POSITIONS
	Level 22	
	Level 21	
	Level 20	
	Level 19	Observer 1 Sarnia
	Level 18	
	Level 17	
Nikkon (4GB) 3/16 on first flight	Level 16	Observer 2 Richard
	Level 15	
	Level 14	
Nikkon (4GB) 3/13 on first flight	Level 13	Observer 3 (student)
	Level 12	
	Level 11	
Nikkon (4GB) 3/10 on first flight	Level 10	Observer 4 (student)
	Level 9	
	Level 8	
	Level 7	
CCTV hardwired to Security Rm.	Level 6	DVD burned after Evacuation
	Level 5	
CCTV hardwired to Security Rm. monitoring final exit door	Levels 4 – LG final exit	DVD burned after Evacuation

APPENDIX A5

EXPLORATORY CASE STUDY

Note: The section numbers in the Appendix for Chapter line up with the numbers in Chapter 5.

A5.3 EXPLORATORY CASE STUDY RESULTS

A5.3.1 Generally

The Exploratory Case Study results are presented for two themes namely:

- *Theme A:The Health and Welfare Canadian 1977 Study – selected results from the Jeanne Mance, Concord and Lasalle 2 Office Buildings in Ottawa, Canada.*

- *Theme B: The 1986 Data Set – selected results from Buildings 1-8 as described in Chapter 5 and presentation of Buildings 3 and 7 as exemplar buildings for further comparison with the 2008-2010 Study in Chapter 7.*

Only the results for Theme B are included in the Appendix as they contain the original data tables which are combined and summarised in Chapter 5.

A5.3.3 Theme B – Exploratory Case Study dataset Results

Extrinsic 1 - stair environment and location

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	53.7	33.1	3.3	0.8	9.1	13	121
2	48.2	44.7	3.5	3.5	0	17	114
3	**61.3**	**34**	**3.3**	**1.3**	**0**	**33**	**150**
4	57.6	38	2.2	2.2	0	45	92
5	73.2	25.6	0	0	1.2	7	82
6	56.5	34.8	6.5	0	2.2	19	46
7	**64.2**	**30.5**	**3.2**	**2.2**	**0**	**20**	**95**
8	53.6	40.5	2.4	3.6	0	19	84
all	58.3	35.3	2.9	1.8	1.7	NA	784

1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree

Table A1: Stair was easy to find

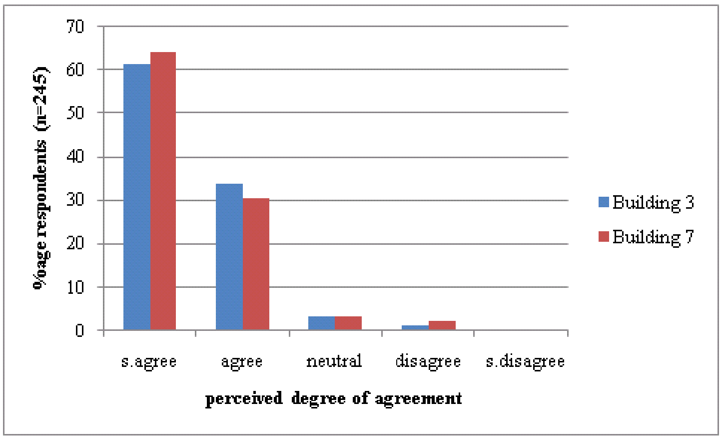


Figure A1: Stair Location - easy to find? (Summary of Buildings 3 and 7)

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	6.8	2.6	23.9	39.3	27.4	13	117
2	6.4	18.3	31.2	26.6	17.4	17	109
3	**0.7**	**9.3**	**33.3**	**38**	**18.7**	**33**	**150**
4	6.5	9.7	30.1	43	10.8	45	93
5	3.7	0	37.5	35	23.7	7	80
6	0	0	20	44	35.6	19	45
7	**3.2**	**7.4**	**34.7**	**40**	**14.7**	**20**	**95**
8	1.2	10.7	26.2	40.5	21.4	19	84
all	3.8	8	30.3	37.8	20.1	N	773

1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree

Table A2 - The stair was too hot / lack of ventilation

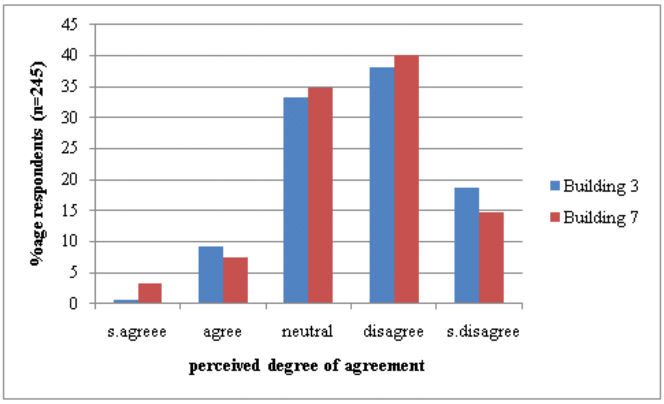


Figure A2: Lack of ventilation to stair shaft? (Summary Buildings 3 and 7)

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	10.8	21.7	23.3	36.7	7.5	13	120
2	10.6	31	25.7	24.8	8	17	113
3	2.7	19.7	27.2	34.7	15.6	33	147
4	5.5	17.6	29.7	37.4	9.9	45	91
5	6.2	11.1	17.3	38.3	27.2	7	81
6	8.9	11.1	26.7	42.2	11.1	19	45
7	7.4	24.5	28.7	29.8	9.6	20	94
8	3.6	28.6	29.8	34.5	3.6	19	84
all	6.8	21.5	26.1	34.1	11.5	NA	775

1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree

Table A3: Time in the stair shaft was too long?

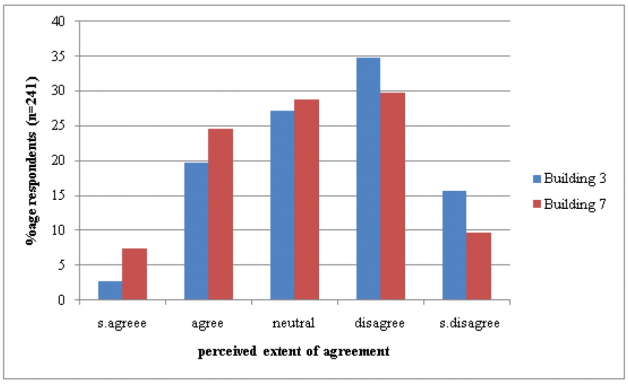


Figure A3: Time in the stair shaft was too long? (Summary Buildings 3 and 7)

Extrinsic 2 – stairs

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	5.8	13.2	22.3	43.8	14.9	13	121
2	1.8	10.8	32.4	44.1	10.9	17	111
3	**0.7**	**6.7**	**25.3**	**54.7**	**12.7**	**33**	**150**
4	0	5.4	23.9	60.9	9.8	45	92
5	1.2	3.7	23.7	52.5	18.8	7	80
6	2.2	2.2	15.6	60	20	19	45
7	**0**	**5.3**	**22.1**	**60**	**12.6**	**20**	**95**
8	2.4	19.3	24.1	43.4	10.8	19	83
ALL	1.8	8.8	24.5	51.7	13.3	N	777

1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree

Table A4: Stair was too steep?

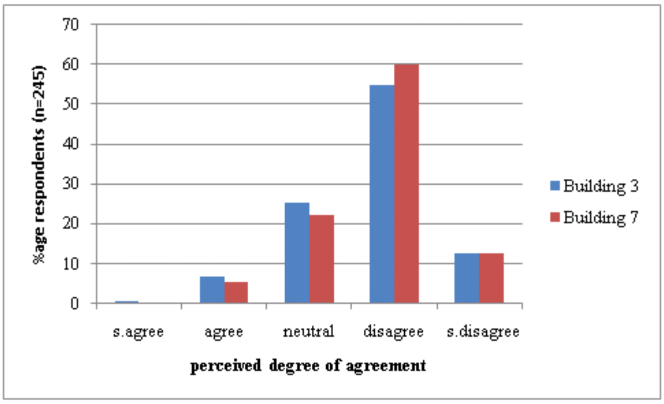


Figure A4: Stair was too steep? (Summary Buildings 3 and 7)

building id	extreme	very much	moderate	slight	not at all	no storey	no cases
1	3.3	6.6	8.2	20.5	61.5	13	122
2	1.8	3.6	7.1	31.3	56.3	17	112
3	**0.7**	**4.8**	**6.2**	**20.5**	**67.8**	**33**	**146**
4	0	4.3	12	20.7	63	45	92
5	1.2	1.2	4.9	13.6	79	7	81
6	2.3	4.7	2.3	20.9	69.8	19	43
7	**1**	**3.1**	**5.2**	**18.8**	**71.9**	**20**	**96**
8	7.5	5	6.3	22.5	58.7	19	80
ALL	2.1	4.3	6.9	21.1	65.4		772

1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all

Table A5: Particular apprehension about getting a safe footing on small treads?

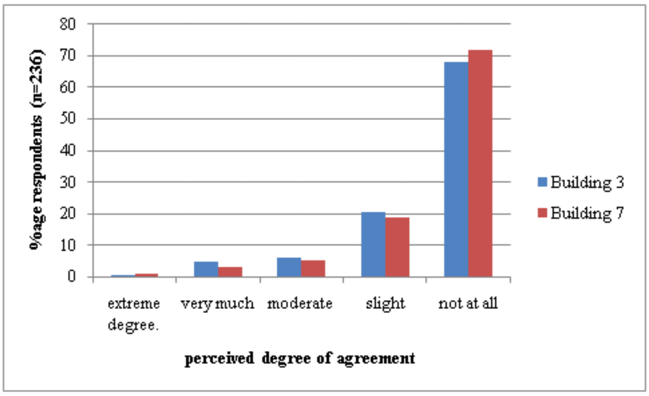


Figure A5: Particular apprehension about getting a safe footing on small treads? (Summary for Buildings 3 and 7)

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	3.4	15.1	16	44.5	21	13	119
2	0.9	5.4	18.9	53.2	21.6	17	111
3	0.7	1.3	15.3	64.7	18	33	150
4	0	2.2	10.8	74.2	12.9	45	93
5	2.5	1.2	16	53.1	27.2	7	81
6	0	0	15.2	58.7	26.1	19	46
7	0	3.2	13.7	64.2	18.9	20	95
8	0	7.2	16.9	55.4	20.5	19	83
ALI	1	4.9	15.4	58.5	20.2	N	778

Table A6: Steps were too slippery?

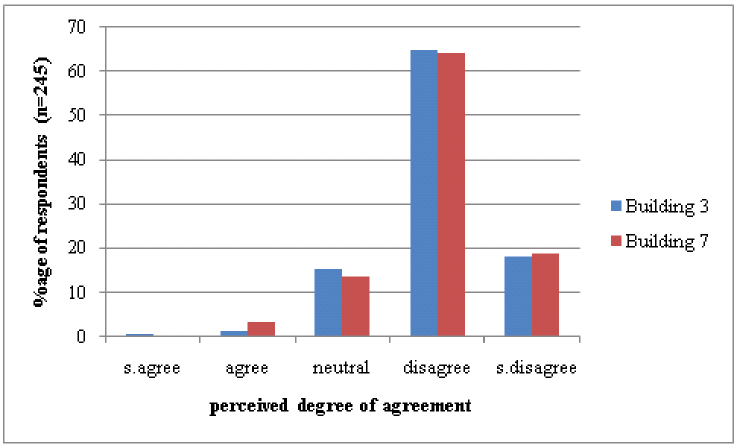


Figure A6: Steps too slippery? (Summary Buildings 3 and 7)

Extrinsic 3 – handrails, lighting and maintenance

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	11.6	19	21.5	15.7	32.2	13	121
2	11.4	20.2	17.5	20.2	30.7	17	111
3	**4.1**	**16.3**	**19**	**17.7**	**42.9**	**33**	**149**
4	31.2	40.9	14	7.5	6.5	45	92
5	7.4	21	23.5	16	32.1	7	81
6	11.6	20.9	9.3	11.6	46.5	19	46
7	**6.5**	**17.2**	**20.4**	**21.5**	**34.4**	**20**	**94**
8	15.4	9	23.1	24.4	28.2	19	84
ALL	11.8	20.4	19.1	17.1	31.6	NA	778
1= an extreme degree; 2= very much; 3= moderate; 4= slight; 5= not at all							

Table A7: Used handrail in descent?

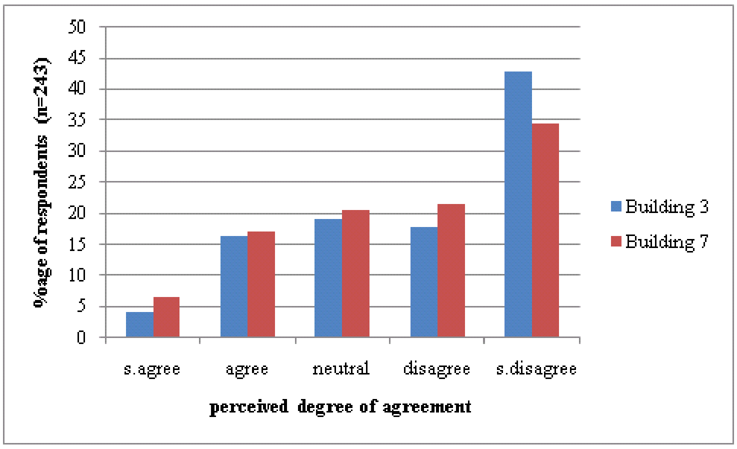


Figure A7: Used handrail in descent? (Summary Buildings 3 and 7)

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	na	na	na	na	na	na	na
2	3.6	5.5	30	45.5	15.5	17	110
3	**7**	**10.7**	**22.1**	**51.7**	**14.8**	**33**	**149**
4	2.2	6.5	14	61.3	16.1	45	93
5	3.7	2.5	18.5	50.6	24.7	7	81
6	6.5	2.2	10.9	65.2	15.2	19	46
7	**1.1**	**9.5**	**17.9**	**53.7**	**17.9**	**20**	**95**
8	0	4.9	23.2	56.1	15.9	19	82
ALL	2.1	6.7	20.6	53.7	16.9	NA	656
1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree							

Table A8: Handrail was awkward to use?

Figure A8: Typical example of handrail rail cross sections - rectangular profile - poor graspability

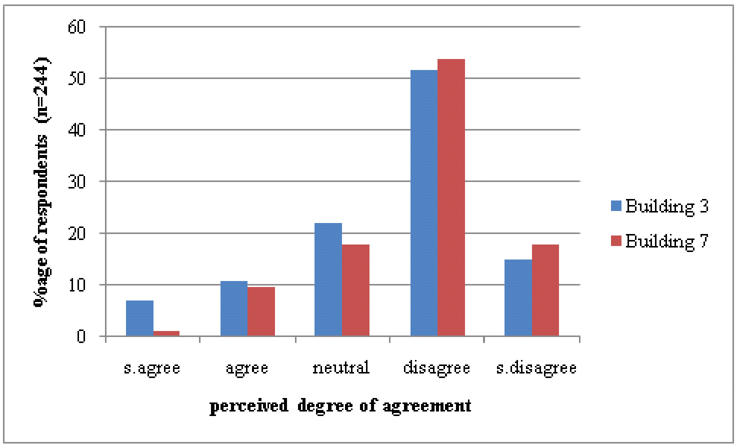


Figure A9: Handrail was awkward to use? (Summary Buildings 3 and 7)

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	6.6	8.3	20.7	47.9	16.5	13	121
2	0.9	3.6	21.6	54.1	19.8	17	111
3	**0.7**	**1.3**	**10.7**	**66.4**	**20.8**	**33**	**149**
4	2.2	4.3	9.8	63	20.7	45	92
5	2.5	2.5	14.8	51.9	28.4	7	81
6	0	2.2	15.2	60.9	21.7	19	46
7	**2.1**	**3.2**	**14.9**	**60.6**	**19.1**	**20**	**94**
8	2.4	6	9.5	64.3	17.9	19	84
ALL	2.3	4	14.8	58.6	20.3	NA	778

1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree

Table A9: Stair lighting was inadequate?

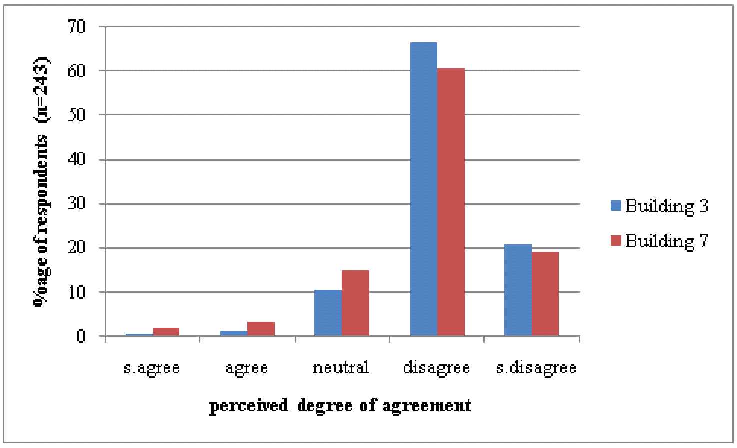


Figure A10: Stair lighting was inadequate? (Summary Buildings 3 and 7)

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	6.6	14.9	34.7	24.8	9	13	121
2	4.5	20.7	41.4	25.2	8.1	17	111
3	**2**	**13.3**	**32**	**38.7**	**14**	**33**	**150**
4	4.3	12.9	29	40.9	12.9	45	93
5	7.6	6.3	34.2	32.9	19	7	79
6	0	2.2	35.6	46.7	15.6	19	45
7	**4.3**	**9.8**	**32.6**	**41.3**	**12**	**20**	**92**
8	6	22.6	25	36.9	9.5	19	84
ALL	4.5	13.8	33.2	34.8	13.7	NA	775

1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree

Table A10: Stair maintenance is inadequate?

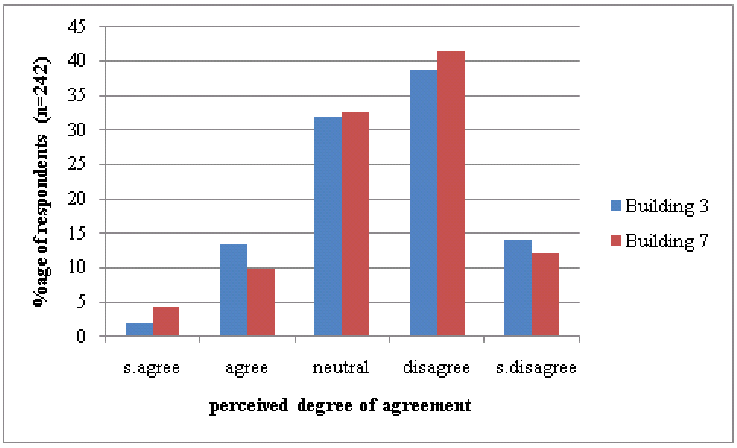
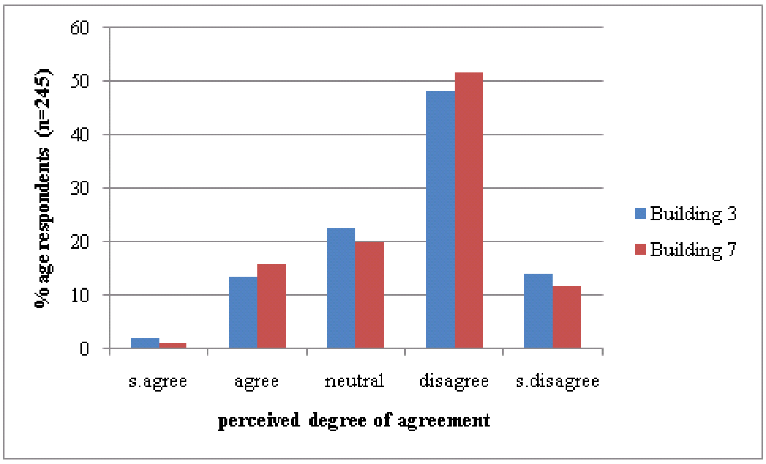


Figure A11: Stair maintenance is inadequate? (Summary Buildings 3 and 7)

Extrinsic 4 - density – others:

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	7.4	10.7	18.2	47.1	16.5	13	121
2	5.5	8.2	26.4	39.1	10.9	17	110
3	**2**	**13.3**	**22.7**	**48**	**14**	**33**	**150**
4	2.2	2.2	15.2	63	17.4	45	92
5	3.7	4.9	18.5	50.6	22.2	7	81
6	2.2	6.5	15.2	52.2	23.9	19	46
7	**1.1**	**15.8**	**20**	**51.6**	**11.6**	**20**	**95**
8	1.2	14.3	19	52.4	13.1	19	84
ALL	3.3	11.4	20	49.8	15.4	NA	779
1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree							

Table A11: Stair was uncomfortably crowded?



FigureA12: Stair was uncomfortably crowded? (Summary Buildings 3 and 7)

building id	s.agree	agree	neutral	disagree	s.disagree	no storeys	no cases
1	6.6	19	14.9	41.3	18.2	13	121
2	6.3	23.4	21.6	38.7	9.9	17	111
3	2.7	17	17	46.9	16.3	33	147
4	2.2	15.1	17.2	48.4	17.2	45	93
5	6.3	3.8	11.4	57	21.5	7	79
6	2.2	6.5	13	54.3	23.9	19	46
7	1.1	23.2	18.9	42.1	14.7	20	95
8	1.2	19	17.9	45.2	16.7	19	84
ALL	3.7	17	16.9	45.7	17.3	N	776

1=strongly agree; 2=agree; 3= are neutral; 4= disagree; 5= strongly disagree

Table A12: Stairs were not wide enough?

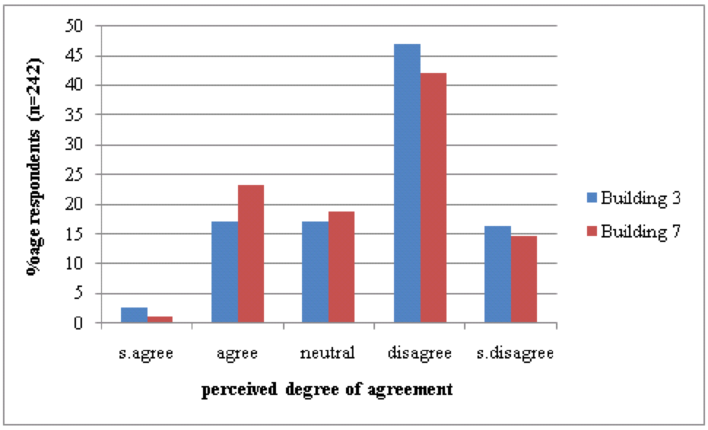


Figure A13: Stair was not wide enough? (Summary Buildings 3 and 7)

Extrinsic 5 - delays – others:

building id	extreme degree	very much	moderate	slight	not at all	no storeys	no cases
1	3.3	6.6	9	23.8	57.4	13	122
2	8.8	13.3	16.8	23.9	37.2	17	113
3	1.3	6.6	16.1	38.3	38.3	33	149
4	3.2	3.2	9.7	23.7	60.2	45	93
5	1.2	3	6.3	23.7	65	7	80
6	0	6.5	8.7	21.7	63	19	46
7	3.2	9.5	18.9	27.4	41.1	20	95
8	2.4	3.7	7.3	28	58.5	19	82
ALL	3.2	6.8	12.3	27.3	50.4	NA	780
1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all							

Table A13: Delay due to slow movers in your group?

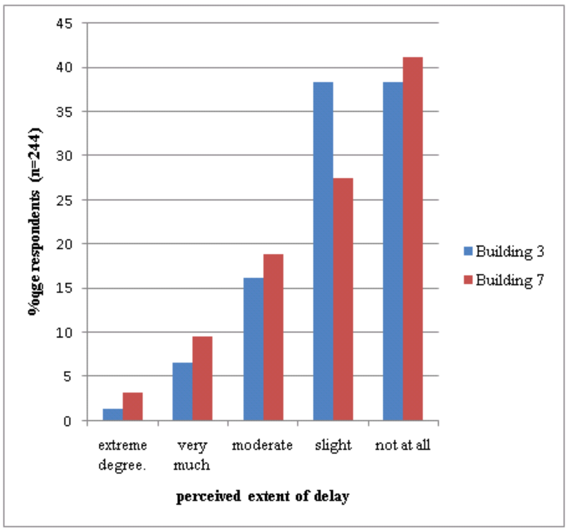


Figure A14: Delay to slow movers in your group? (Summary for Buildings 3 and 7)

Extrinsic 6 - group formation

building id	extreme degree.	very much	moderate	slight	not at all	no storeys	no cases
1	5.7	15.6	13.1	12.3	53.3	13	122
2	7.9	25.4	23.7	14.9	28.1	17	114
3	8.9	21.8	21.8	21.8	26.5	33	147
4	4.4	17.8	22.2	18.9	36.7	45	90
5	0	10	21.2	22.5	46.2	7	80
6	14.3	14.3	16.7	9.5	45.2	19	42
7	1.1	12.6	20	20	46.3	20	95
8	6.3	10	26.2	15	42.5	19	80
ALL	5.7	16.9	20.6	17.4	39.4	NA	770

1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all

Table A14: You made an effort to enter the stairs as part of a group of people you knew?

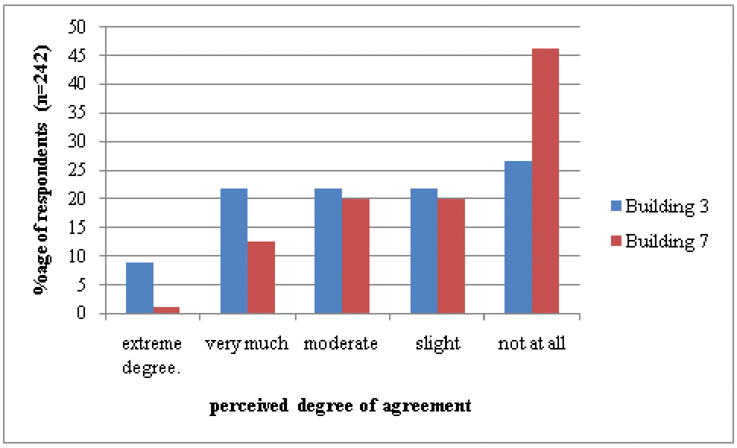


Figure A15: You made an effort to enter the stairs as part of a group of people you knew? (Summary of Buildings 3 and 7)

building id	extreme degree.	very much	moderate	slight	not at all	no storeys	no cases
1	13.3	38.3	20.8	13.3	14.2	13	120
2	12.3	44.7	21.9	7.9	13.2	17	114
3	9.5	39.5	29.3	10.9	10.9	33	147
4	5.4	52.2	18.5	13	10.9	45	92
5	4.9	28	41.5	17.1	8.5	7	82
6	14.3	33.3	19	16.7	16.7	19	42
7	5.3	31.6	30.5	14.7	17.9	20	95
8	13.7	27.5	32.5	15	11.2	19	80
ALL	9.7	37.8	26.8	13	12.7	NA	772

1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all

Table A15: The people close to you in the stair well are well known to you?

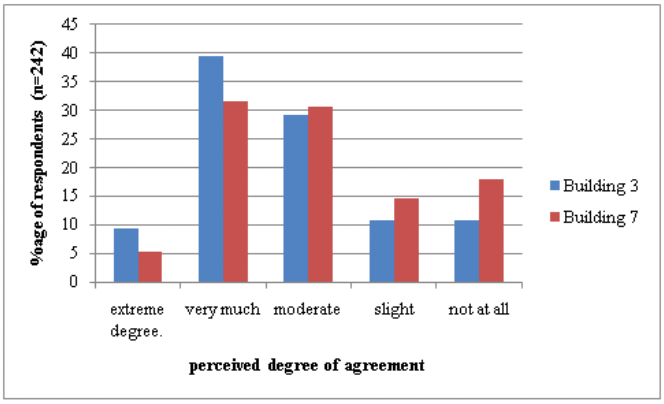


Figure A16: The people close to you in the stair well are well known to you?
(Summary of Buildings 3 and 7)

Intrinsic 1 – confidence

building id	extreme	very much	moderate	slight	not at all	no storey	no cases
1	3.3	2.5	8.2	28.7	57.4	13	122
2	0.9	2.7	8	30.4	58	17	112
3	0.7	1.4	3.4	19.6	75	33	148
4	2.2	4.3	8.6	26.9	58.1	45	93
5	1.2	1.2	2.5	10	85	7	80
6	4.7	4.7	7	16.3	67.4	19	43
7	0	4.2	7.3	22.9	65.6	20	96
8	3.7	3.7	10	20	62.5	19	80
ALL	1.8	2.8	6.7	22.7	65.9		774
1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all							

Table A16: Apprehension about personal safety whilst descending the stairs?

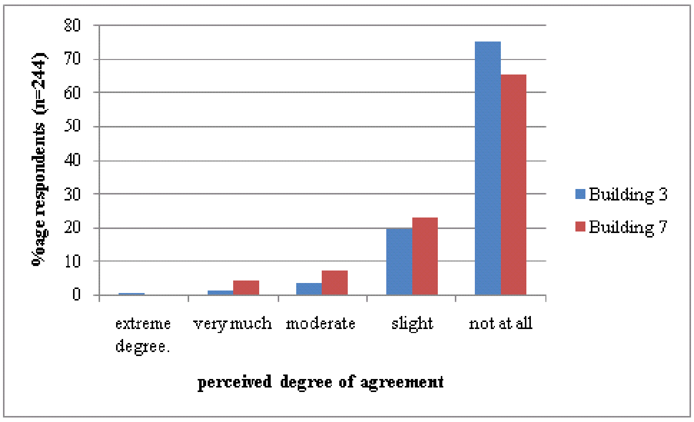


Figure A17: Apprehension about personal safety whilst descending the stairs? (Summary of Buildings 3 and 7)

Intrinsic 2 – functional limitations

building id	extreme	very much	moderate	slight	not at all	no storey	no cases
1	0	0	5.7	7.4	86.9	13	122
2	0.9	5.4	10.7	22.3	60.7	17	112
3	2	3.4	4.8	23.8	66	33	147
4	3.2	5.4	12.9	39.8	38.7	45	93
5	0	1.2	2.5	3.7	92.6	7	81
6	2.3	4.7	9.3	14	69.8	19	43
7	0	3.1	0	10.4	86.5	20	96
8	1.2	2.5	8.7	8.7	78.7	19	80
AL	1.2	3.1	6.6	17.1	72.1		774

1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all

Table A17: Weakness / pain in your knees?

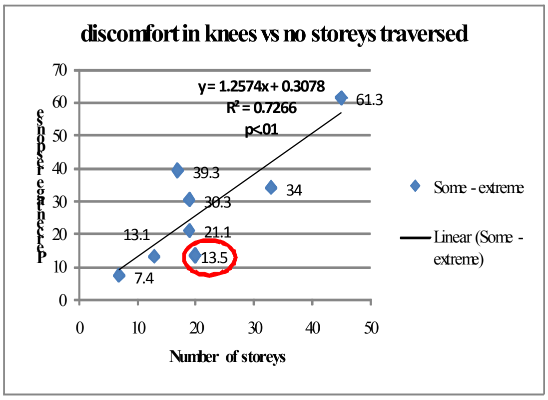


Figure A18 - Discomfort in knees vs. number of storeys traversed

building id	extreme	very much	moderate	slight	not at all	no storey	no cases
1	0	0.8	2.5	3.3	93.4	13	122
2	0	0	0	5.4	94.6	17	112
3	0	0	1.4	6.8	91.8	33	147
4	0	2.2	1.1	4.3	92.5	45	93
5	0	0	1.2	2.5	96.3	7	81
6	0	0	0	4.7	95.3	19	43
7	1	0	1	2.1	95.8	20	96
8	0	0	1.2	3.7	95	19	80
AL	0.1	0.4	1.2	4.3	94.1		774

1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all

Table A18: Discomfort or tightness in your chest?

building id	extreme	very muc	moderate	slight	not at all	no storey	no case
1	0	1.6	1.6	11.5	85.2	13	122
2	0	0	4.5	17.1	78.4	17	111
3	0	0	2.7	16.2	81.1	33	148
4	0	2.2	3.2	26.9	67.7	45	93
5	0	0	2.5	4.9	92.6	7	81
6	0	0	0	18.5	81.4	19	43
7	1	1	1	3.1	93.8	20	96
8	0	0	5	11.2	83.7	19	80
AL	0.1	0.6	2.7	13.7	82.9		774
1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all							

Table A19: Fatigue generally?

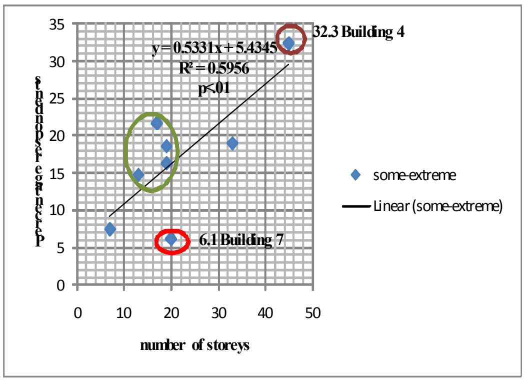


Figure A19: Fatigue vs. no of storeys traversed

building id	extreme	very muc	moderate	slight	not at all	no storey	no case
1	0	1.6	1.6	11.5	85.2	13	122
2	0	0	4.5	17.1	78.4	17	111
3	0	0	2.7	16.2	81.1	33	148
4	0	2.2	3.2	26.9	67.7	45	93
5	0	0	2.5	4.9	92.6	7	81
6	0	0	0	18.6	81.4	19	43
7	1	1	1	3.1	93.8	20	96
8	0	0	5	11.2	83.7	19	80
AL	0.1	0.6	2.7	13.7	82.8		774
1= An extreme degree; 2= very much; 3= moderate; 4= Slight; 5- not at all							

Table A20: Dizziness or problems with your balance?

building id/condition	extreme	very much	moderate	slight	not at all	no storeys	no cases
3 - knees	2	3.4	4.8	23.8	66	33	147
3 - chest	0	0	1.4	6.8	91.8	33	147
3 - fatigue	0	0	2.7	16.2	81.1	33	148
3 - balance	0	0	2.7	16.2	81.1	33	148
7 - knees	0	3.1	0	10.4	86.5	20	96
7 - chest	1	0	1	2.1	95.8	20	96
7 - fatigue	1	1	1	3.1	93.8	20	96
7 - balance	1	1	1	3.1	93.8	20	96

Table A21: Intrinsic functional limitations
(Summary for Buildings 3 and 7)

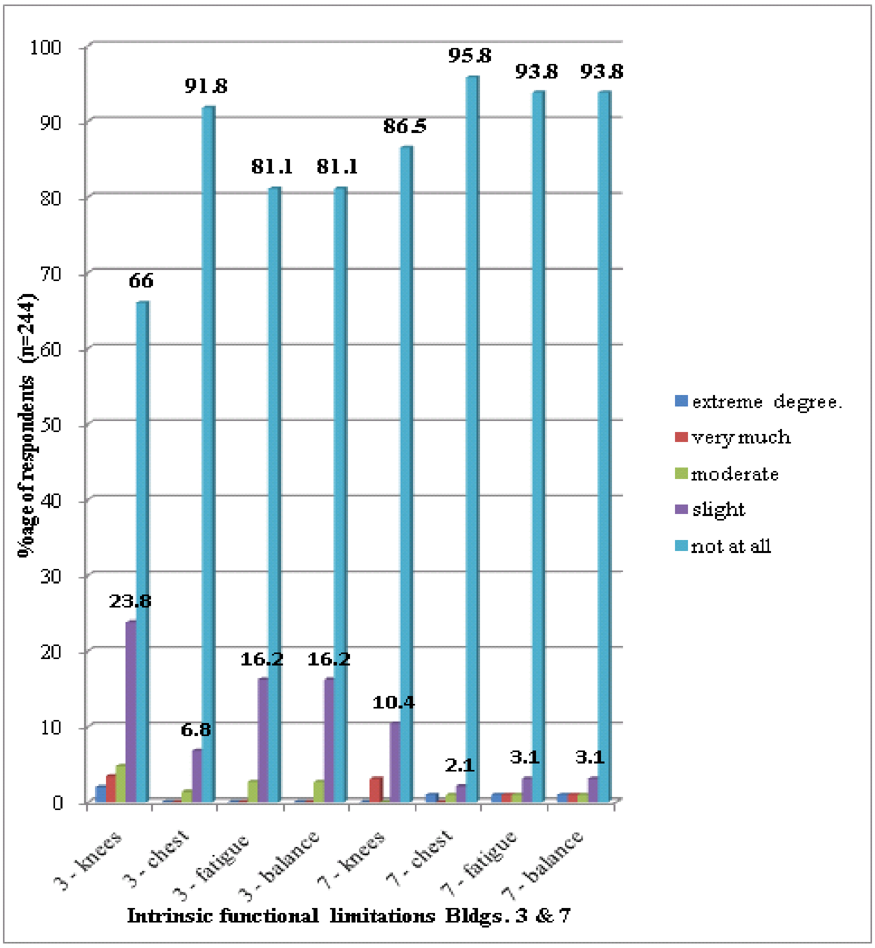


Figure A20 - Intrinsic functional limitations for Buildings Three and Seven vs. number of storeys

Intrinsic 3 – fatigue and distance

Buildings Numbers			Building 3 (%age shown)		Buildings 2 and 4 (%age shown)	
Rating scale particulars			Storey Rating	Fatigue Rating	Storey Rating	Fatigue Rating
Fatigue rating	No storeys coped	Rating no.				
extreme degree	<5	1	3.3	0	0	5
very much	>5 to <9	2	6	0	1.1	5.8
moderate	>9 to 14	3	6	2.7	3.8	7.2
slight	>14 to 19	4	3	16.2	22	6.1
not at all	> 20 storeys	5	81.7	81.1	73.1	24.1
Regression details: R^2 = 0.9522 for Building 3 and 0.6541 for Buildings 2 and 4. ($p<0.05$)						
Forerunner to later IPAQ survey measuring level of activity in METS per week.						

Table A22: Number of storeys can cope with by perceived level of fatigue (n=381)

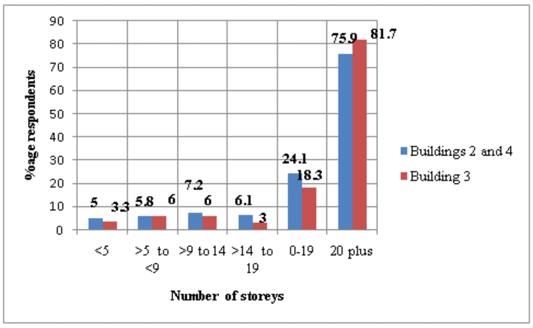


Figure A21: Number of storeys can cope with by perceived level of fatigue (n=381)

Summary of Exploratory Case Study dataset Findings – Theme B: (Ishikawa Chart Model:

The results for the Theme B analysis are summarised in the Ishikawa Chart shown in Figure A22 below:

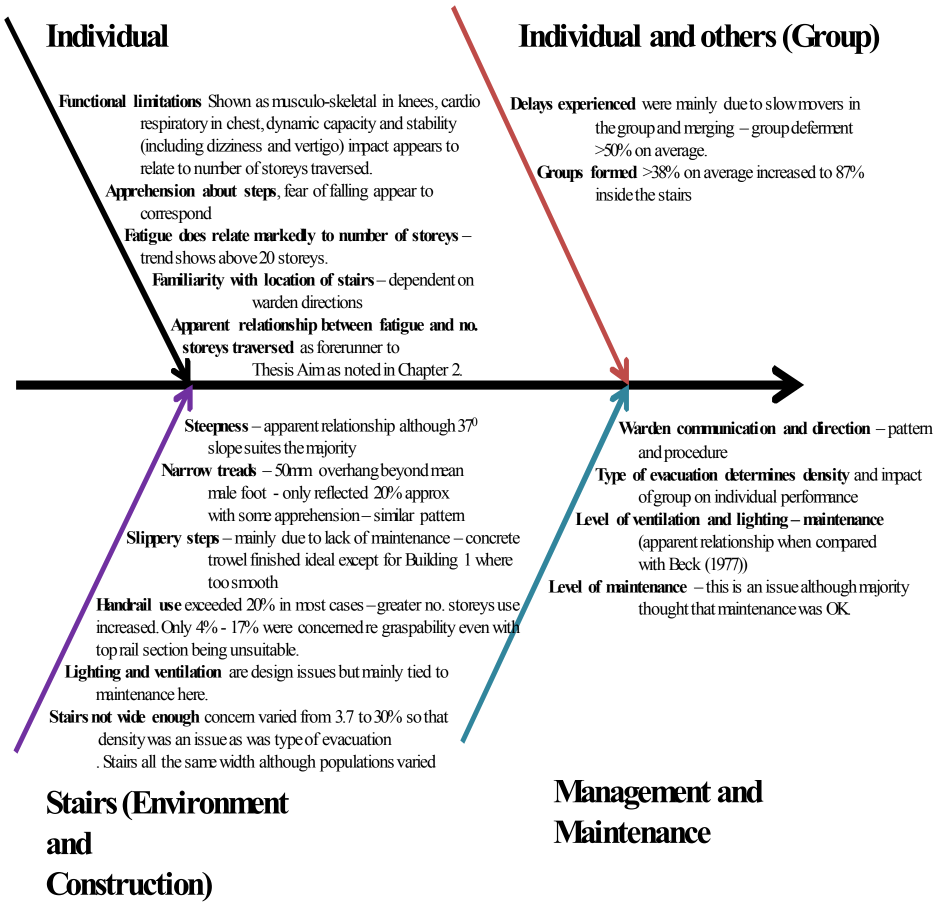


Figure A22: Summary of Exploratory Case Study dataset Theme B Results

APPENDIX A6: EXPLANATORY CASE STUDIES

Contains the following:

- Delphi group outcomes and procedures including main contextual classifications and also to provide core consistencies for Directed Content Analysis Studies.
- Coding regime for Directed Content Analysis Studies.
- Tables of comments transcribed from Content Analysis Study documents coded in the core consistencies and tables of subcategories.
- Focus Group Studies in their entirety

Note: The section numbers in Appendix A6 follow those used in Chapter 6.

A6.2 Coding Regime for Content Analysis and Focus Group Studies

The main classifications are:

- The Individual
- The individual and others on the stairs
- Stairs (design and construction
- Management and maintenance

The category coding regime follows:

<u>YOU / INDIVIDUAL (Y):</u>

Condition (YC)*

- Obesity (YC1)
- Fitness (YC2)
- Strength (YC3)
- Co-morbidities affecting stance and gait (YC4)

Behaviour (YB)*

- Aggressive or non-altruistic – demand help from others or non self-starter (YB1)
- Altruistic – would not slow others down (YB2)
- Readily accept assistance and risk (YB3)

Mental attributes and determination (YM)*

- Have condition and will help themselves – willpower (YM1)
- Decisiveness (YM2)
- Other – Attitude (YM3)

Spatial and Experiential (YS)*

- Awareness of space required to assist/ to pass/ to rest (YS1)
- Previous drills/ building element knowledge (YS2)

** Sub category coding within each core consistency classification*

YOU AND OTHERS (OG):

Group Dynamics and Capacity to Assist (OGD)*

- Cohesion and commitment (including territory) (OGD1)
- Altruism and assisting (OGD2)
- Risk of actions associated with assisting (OGD3)

Risk factors (OR)* Aggressive or intimidating action that may place other members of the group at risk including falling.

Group knowledge/ commitment (OGK)*

- Building element knowledge (OGK1)
- Way finding / experience of previous drills as group (OGK2)
- Level of training to assist (OGK3)

** Sub category coding within each core consistency classification*

STAIR DESIGN, CONSTRUCTION AND ENVIRONMENT (S):

Stair width and refuge (SS)*

- Stair width and layout (SS1)
- Number handrails (SS2)
- Refuge - Place to rest that will not hinder flow (SS3)

Obstruction (SO)*

- Element of obstruction that interferes with or prevents evacuation (e.g. locked doors) (SO1)
- Equipment defect that affects flow such as illumination, no ventilation, other. (SO2)

** Sub category coding within each core consistency classification*

<u>MANAGEMENT AND MAINTENANCE (M):</u>

- **Central Organisation:** preparedness/ resources/ policy/ commitment/adaptability/ decisiveness culture/ currency/ experience. Includes negative and positive aspects. (MC)*
- **Tenant Organisation:** preparedness/ resources/ policy/ commitment/adaptability/ decisiveness culture/ currency/ experience. Includes negative and positive aspects (MT)*

** Sub category coding within each core consistency classification. No mention made of Maintenance in either of the Studies*

A6.3 DELPHI GROUP PROCESS AND OUTCOMES

A6.3.1 Overview

The purpose of the Delphi Group is described in Chapter 3 along with its justification and process involved. A group of eight members is seen as being the optimum (Linstone and Turoff, 2002). This number was achieved but in an unconventional way. The author, being a member of the 1980 Study Delphi Group participated in the initial part of the process as a participant in the US Delphi Group with his colleague, Jake Pauls, who was also a member of the same Delphi Group. The author was therefore considered as an expert as permitted in the Case Study Research Method (Yin, 2009) but his participation was limited by agreement with the "Group" members.

The Delphi Group comprised two sub-groups as outlined in Chapter 3 being:

- US Sub Group being engineering science based where the members were leading researchers in the field:
  - Jake Pauls (original NRCC expert, 1977)
  - Jason Averill, Project Leader, NIST, (Averill et al, 2005)
  - Erica Kuligowski, Researcher Specialist in Human Behaviour in Emergencies, NIST, (Kuligowski and Hoskins, 2010)
  - Hamish Maclennan, former Principal Researcher, UTS, (Nelson and MacLennan, 1988).

- UK Sub Group being basically health science based comprising experts from the Building Research Establishment, Manchester Metropolitan University, University of Loughborough and the NHS (UK) in the field of bariatric care.
    - Mike Roys – Research Scientist and Architect - Building Research Establishment, Stair Safety. (Roys, 2006)
    - Neil Reeves, Research Fellow, Biomechanics, Stairs, Metropolitan Manchester University. (Reeves et al, 2008).
    - Anita Rush, Specialist Consultant in Bariatric Care, NHS, member of University of Loughborough Research Team on Safe Handling Systems for Bariatric Patients, (Hignett, 2008).
    - Hilary McDermott, Researcher and Environmental Psychologist, School of Sports Science, University of Loughborough
    -

The US sub group prepared an overview of the whole field of stair use and safety using the Ishikawa Chart Model (branch structure) prepared by the author and based on the Literature Review as presented in Chapter 3.

The US Subgroup members with the author acting as the facilitator then completed each branch of the Model in the context of the main outcome being the safe descent of multiple flights of stairs in office buildings in both emergencies and trial evacuations.

The UK Subgroup members with the author acting as a non participatory facilitator then challenged the US Subgroup's outcome with the general comment:

"The initial outcome is far too involved and complex to provide the inclusive framework required. It provides a good "aide-memoire" for detailed analysis."

(UK Subgroup 2008)

The UK Subgroup basically summarised the Model providing the author with direction in breaking down the elements noted on the branches in the light of the health science and ergonomics based research in the United Kingdom. The final model only contains four main branches which agrees with the body of research as depicted by Templer (1992), Startzell (2000), Reeves et al (2008), Roys (2005) and Pauls (1977, 2007 and 2011).

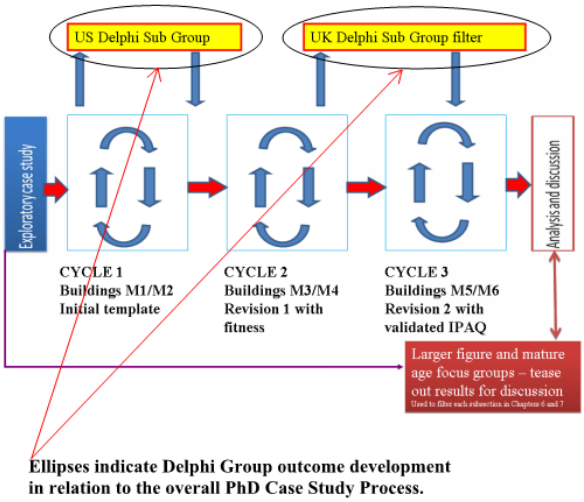


Figure A23: Interaction of Delphi Group with PhD Case Study Process

The outcome of the Delphi Group deliberations is presented as completed Ishikawa Charts with explanations as required as the "Results" of these deliberations. In the case of the UK Subgroup the Ishikawa Chart branches are somewhat sparsely populated in order that the author could "flesh" them out as described. The fleshing out was carried out in association with the appropriate experts so that a selective interview technique was added to the Delphi Group method because of the timing of the PhD Case Study process steps.

A6.3.2 Results for Delphi Group Process

US Delphi Sub Group

The outcome is summarised in Figure A24 below. The branches or the grouping of the vital issues for each stair user, occupant or office worker evacuation scenario were considered to be:

- User characteristics and things carried/worn (intrinsic)
- Acute or chronic condition (intrinsic)
- Psycho-social/ neurological condition (intrinsic)
- Stair enclosure and environment (extrinsic)
- Stair construction (extrinsic)
- Composition of descent task (scenario specific)

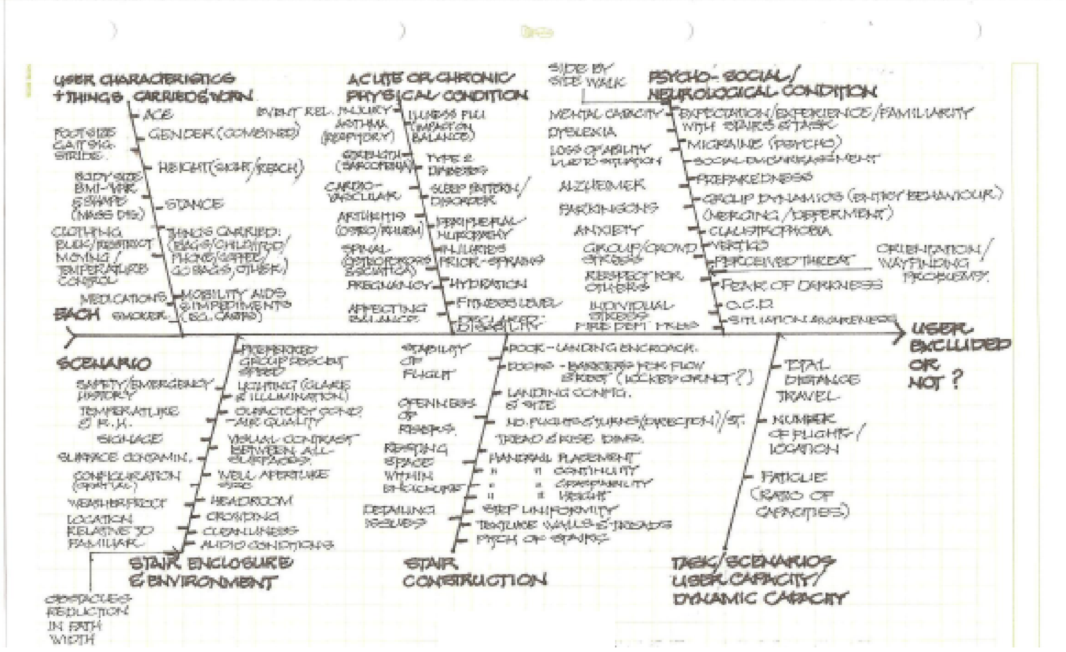


Figure A24 US Delphi Sub Group Ishikawa Chart Outcome

The branches are fleshed out further detail which basically corresponds with the work of Templer (1992), Archea et al, 1979 and Pauls (1977, 1988 and 2002) and then many of the findings from the WTC 9/11 studies (Averill et al, 2005). No doubt some of the post WTC9/11 work being undertaken at the time at NIST when the Delphi Group meeting was held and reflected in the then future publications (Peacock et al, 2009) was mirrored in the details added to each of the branches.

The one problem faced by the author was the complexity of the research questions that were raised. There appeared to be no overall quantitative measures that could have become an independent predictor variable for each scenario such as the "time to reach the ground". The latter can be related to most of the extrinsic and intrinsic factors as a means of determining the difficulty or confidence users have in going down the stairs e.g. in relation strength (Stel et al, 2003), functional limitations (Tiedemann et al, 2007 and Fritz, 2009) and stair slope (Riener et al, 2002). This was the main factor that concerned the UK Subgroup whose outcome is presented in the next section.

UK Delphi Sub Group Results

The UK Delphi Sub Group drew the facilitator into their discussion to clarify details of the proposed PhD Case Study. This request required the facilitator to review his role and change to that of the author contrary to the role of a facilitator. The author agreed to this and clarified the aim and objectives. He also questioned the need for an emergency scenario based user analysis if the PhD Study was to be focussed on trial evacuations. At this point the author resumed his role of facilitator. The Group after further discussion stated that there was a need to simplify the Model.

The frequency and organisation of trial evacuations depend on the commitment of the employer and/or the owner of the building to occupational health and safety. This commitment is reflected in the emergency evacuation plan and procedures for the building. Management can therefore have a direct impact on the frequency and the procedures followed in trial evacuations and the behaviour expected from the workers or occupants. The UK Sub Group was of the opinion that "Management and Maintenance" could determine the grouping of the occupants, the evacuation sequence and strategy as well as the state and condition of the stairs and the stairwell.

The branches were then simplified from the US outcome as follows:

- The Individual or "You"
- The Group or "The Individual and Others"
- Stairs and Environment (Stairs, Design, Construction and Environment)
- Management and Maintenance

The **"Individual"** comprised all the intrinsic factors together in terms of age, gender, mass, functional limitations, psycho-social and neurological factors, and abilities/ experience.

The **"Group"** reflected the impact of group size, composition, cohesion, prior member location and number of relationships, and where group was formed. It also concerned where the groups were formed voluntarily or as part of the management procedure. Group dynamics, behaviour (altruistic or aggressive), and commitment were also added.

The **"Stairs, Design, Construction and Environment"** comprised those factors shown to be critical by the research. Roys (2005) was the source for this so that the following factors were included; tread width, uniformity of step geometry, illumination, number, height and graspability of handrails, contrast between surroundings and steps, legibility of steps, slip resistance of steps, and number of steps per flight. Other factors that were included after further consultation were pitch or riser height, contrast of handrails, step edge conspicuity, width of stairwell, distractions, and encroachments.

"Management and Maintenance" comprised the emergency organisation makeup (central and local). It also included the legislative context, strategy and planning process (authoritative vs. participative), procedures, and frequency of drills. Feedback was also considered to be vital following something similar to the PDSA[4] cycle. Emergency instructions and scenario practice were also mentioned.

The UK Ishikawa Chart Model still contains all issues presented in the US outcome (Figure A24) and was used in its skeleton form as the basis for gathering information in the focus groups, reviewing the literature (see Chapter 3) and the content analysis of Dwyer and Flynn (2004) and is presented in Figure A25 below.

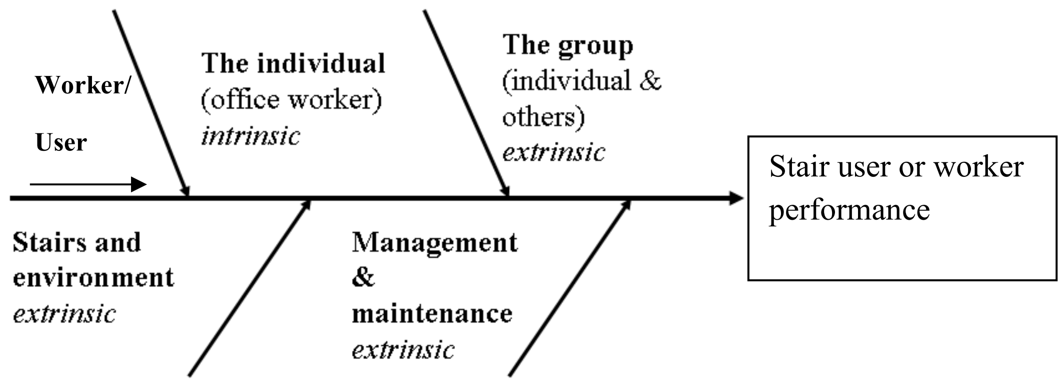


Figure A25 UK Delphi Group Ishikawa Chart as a Skeleton

[4] Plan Do Study Act

A6.4 CONTENT ANALYSIS

A6.4.1 Generally

Section A6.4 is concerned with the Content Analysis of two sets of media. One is a collection of survivor stair user responses from Towers 1 and 2 of the WTC 9/11 Incident compiled by Dwyer and Flynn (2004). The other is a series of responses on a New York Times Blog site dealing with the physical challenge of going down multiple flights of stairs facilitated by Parker-Pope (2008). The connection between these two studies and the Focus Groups is shown in Figure A26 below.

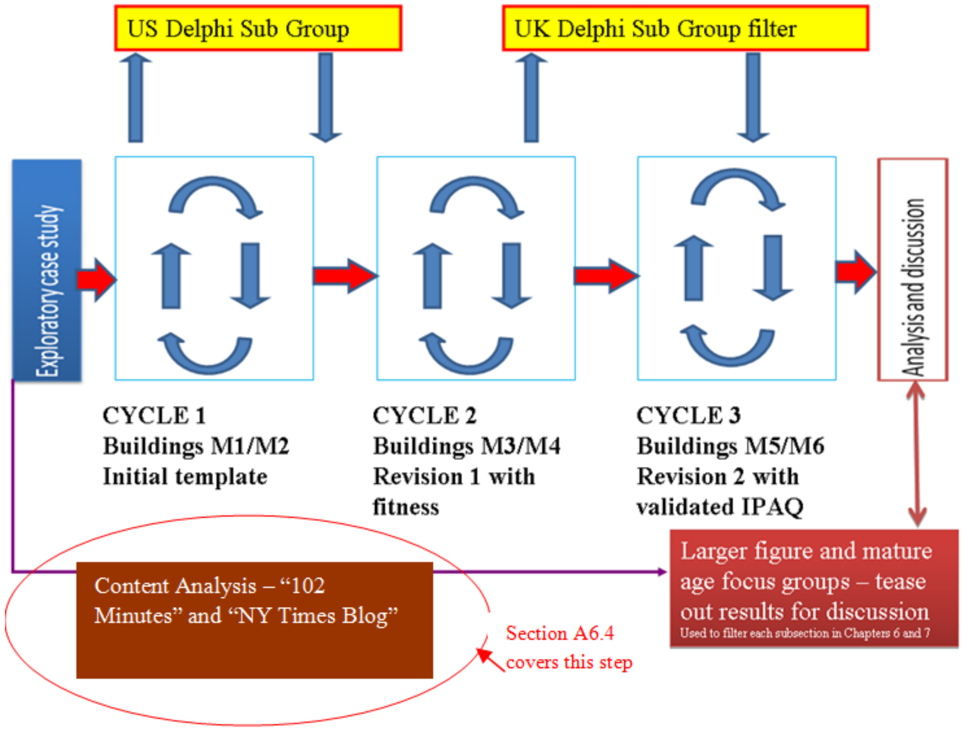


Figure A26: The Content Analysis Process Step and the PhD Case Study Process

Content analysis is seen as acceptable as a research method and approach because of a similar engineering science study carried out by Fahy and Proulx (2005) and the method followed is that outlined in Chapter 3 where a directed approach was used to establish some core consistencies (Hsieh and Shannon, 2005 and Zhang and Wildemuth, 2009). The core consistencies as explained in Chapter 3 were those representing the branches on the UK sub group model in Figure A25. These core consistencies were also used in the Focus Groups and are presented in Section A6.5

.

The Results are presented in the next section comprise:

- Schedules of core consistencies where data is extracted directly from the text (Dwyer and Flynn, 2004 and Parker-Pope, 2008).
- Coding framework for the Core Consistencies to facilitate some further quantitative analysis on the frequency of responses (permitted as a pluralist research technique (Amaratunga et al, 2002) as an alternative to other strictly qualitative techniques).
- Analysis of Results in tables.

A6.4.2 Results (Schedules, coding and analysis)

Each of the following sections is split into two subsections according to the publication analysed.

Schedules

A sample of the specimen schedule is shown in Figure A27 below:

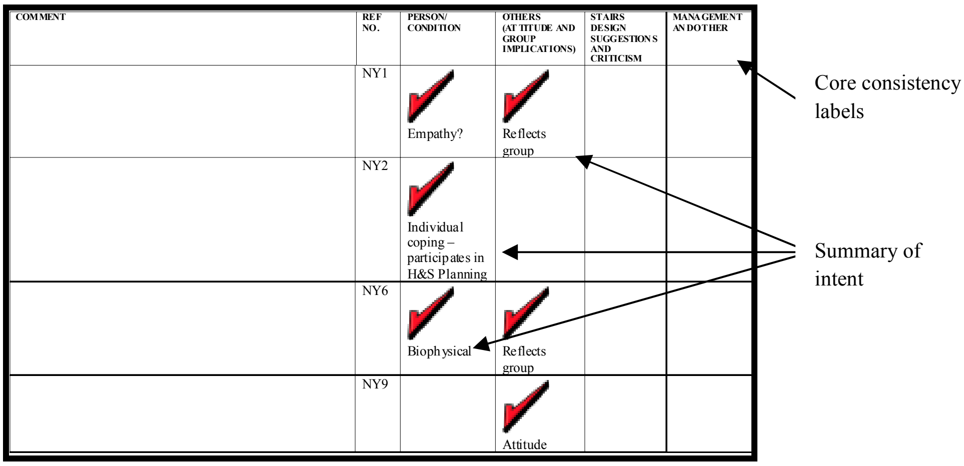


Figure A27: Specimen Table for Core Consistencies

The direct quotation or context of paragraph is inserted in the "COMMENTS" column initially coded, supplied with a reference number (e.g. NY1 or 102.1) and then allocated to its applicable core consistency. These tables (Figure A27) are known as the "Schedules" and are presented in the subsequent two subsections.

102 Minutes – (Dwyer and Flynn, 2004)

The outcomes of the Content Analysis of Dwyer and Flynn (2004) mainly focus on the interaction between survivors as groups, between groups and wardens/ evacuation organisations and to a certain extent between survivors and stairs.

Table A31 to Table A50 comprise schedules 1-20 which show that there were:

- 66 abstractions from the actual document (102.1-102.66)
- 29 coded as "You", 31 as "Group", 21 as "Stairs and 37 as "Management"
- Summarised as shown in Table A30 below:

Core Consistency	Number of Codings	Percentage of Total Codings		Percentage of Total Abstractions	
You	29	29/118	25%	29/66	44%
You & Others	31	31/118	26%	31/66	47%
Stairs & Construction	21	21/118	18%	21/66	32%
Management & Maintenance	37	37/118	31%	37/66	56%

Table A30: Frequencies of classifications against core consistencies (Dwyer and Flynn, 2004).

The percentage of total abstractions shows that the main core consistency was "Management" followed by "Groups", "You" and "Stairs". 691"Management" comments mainly involved actions of wardens which can be summarised as "altruistic". This type of behaviour was by far the most frequently encountered across three out of the four core consistencies and confirms the findings of Fahy and Proulx (2005). A selected cross section of the comments from Schedules 1-20 (Table A31 to - Table A) are shown below:

<u>Comment 102.1</u>

"The immediate challenges these people faced were not geopolitical but intensely local; for instance, to open a jammed door, navigate a flaming hall way, or climb dozens of flight of stairs. Occupants had to care of themselves and those around them........."
Dwyer and Flynn (2004, p.xxi). Covers all four core consistencies.

<u>Comment 102.5</u>

'"Grab your bag," Yagos said. "We're going" Next to them, Ann McHugh also rose to leave.....' ***Dwyer and Flynn (2004, p24). Applies to the Group core consistency dealing with the formation of a group on the floor in the work area. The workers were work colleagues.***

<u>Comment 102.9</u>

"....Many of the people who worked for the bank had been in the building in 1993 so the memory of the calamity ran just beneath the surface......That experience had helped turn emergency preparations into a near religion amongst employees. People learned where the fire stairs were.......One of the banks leaders had sent a memo making their policy

clear.....people were the bank's assets....." **Dwyer and Flynn (2004, p29). Past experience resulted in "work culture" of preparedness and a high level of management commitment to the safety of the workers. This is "local management" as opposed to "central management" of the Port Authority The core consistencies involved are "You", "Group" and "Management".**

Comment 102.20

"The instruction to the caller from Morgan Stanley was especially important. Morgan Stanley occupied twenty two floors and over 2000 people worked for the company. An executive for the bank, Ed Ciffone, had overseen years of intense evacuation programmes, and one of his deputies, Rick Rescorla, had led the drills with a zeal that seemed near evangelical. ... Now it made sense. Their wardens pulled out megaphones and began to drive the Morgan staff out of the building."

Dwyer and Flynn (2004, p.72). Shows the impact of a committed and prepared organisation who was also a large tenant. Groups here were most likely a mixture of work colleagues from a particular department or team and those formed in transit to the stairs following the warden's instructions. The core consistencies involved were "Groups" and "Management". If this comment is read in conjunction with comment 102.19 then the potential conflict can be seen with central management directions.

Comment 102.22

"Along the way Foodlum had tired – she had just finished a challenging chemotherapy series for cancer, and was about to start radiation – but her boss...nudged her along".

Dwyer and Flynn (2004, p.76). Shows individual functional limitation and altruistic behaviour from her boss so that the core consistencies involved are "You" and "Group" as there are two people who would have occupied the space on the stairs and who, in other situations may have caused platooning (Templer, 1992).

Comment 102.24

"The single-minded abandon of Michael Sheehan's departure ....should have carried him clear of the tower by 9:02, but several developments managed to slow him down...When he came across a heavy woman...at the 10th floor, Sheehan ....walked down with her ....out of the building."

Dwyer and Flynn (2004, p.90). Shows that overtaking occurred so that single-minded behaviour may have been initial behaviour but this was placed by altruistic behaviour with the large woman whom he assisted for 10 floors until they were out of the building. The applicable core consistencies are "You", "Group" and "Stairs". Overtaking did occur so that Sheehan may have moved through group territories. A group was formed in the stairs and on other occasions may have slowed others behind as the group would have occupied the stairs. Rest space would have been appropriate and the stairs were not wide enough as demonstrated by others (Peacock et al, 2009).

Comment 102.30

"He fixed his gaze on the lip of each step; defined by the glow in the dark stripe and started ....he navigated this line down 1512 steps that led from the 84th floor of the South Tower to the lobby..." **Dwyer and Flynn (2004, p.101). This is an example of the effectiveness of**

the photo luminescent nosing strips as a way finding tool. It also demonstrates how stair users who are focussed can go down multiple flights of stairs safely. There were others involved as well. Core consistency here is "Stairs".

Comment 102.36

"The line moving along the stairs immediately resumed a fast but steady pace...Soloway took the arm of a woman having a panic attack....Salovich carried the bag of another woman hearing about her two children..."Thirtieth floor'" Salovich called out. "It's all downhill from here." ***Dwyer and Flynn (2004, p.118). This is a classic example of altruistic behaviour and group dynamics where Salovich did not want to compromise the safety of others. His purpose was to help the slow mover and keep the line moving. Core consistencies of "You" and the "Group" apply.***

Comment 102.53

"I've found an exit," he said, and he led them to a door.......She saw a thin man behind her in the stairs........Another colleague, Sankara Velamuri escorted Tembe with his bad knee..." ***Dwyer and Flynn (2004, p.191).Core consistencies of "You" and "Group" apply. It could be argued that "Stairs" could apply as well but the predominant themes are altruistic behaviour and interaction between groups and their members. It shows the value of a "leader" (Jones and Hewitt, 1985) that others are prepared to follow.***

Comment 102.65

"(North Tower) Reese had severe asthma. Everything about the long descent – the heat, the anxiety – tightened the clamp around her throat....her colleague tried soothing assurance, pep talk, pleading... only 5 floors to go and they would be out of the building...she had to sit." ***Dwyer and Flynn (2004, p.228). Shows that respiratory problems are a functional limitation that relates to distance or the number of storeys. Demonstrates altruistic behaviour and the need for a space to rest even if she only had 5 storeys to go down. Core consistencies of "You", "Group" and "Stairs" apply.***

The above comments provide a comprehensive cross section of the 66 comments. When considered in the context of the Aim and Objectives of the PhD Case Study it provides a valuable insight into the challenge of going down multiple flights of stairs, the natural tendency of group members to help others, the relationship between fitness and distance traversed, the risk to the group of assisting others in terms of physical effort, and the impact of local and central management on stair user/ occupant behaviour.

The core consistencies are now coded in greater detail according to the content and intent of the abstracted comments. These details are outlined further in the next section under “Coding”.

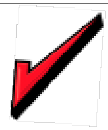
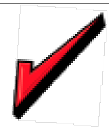
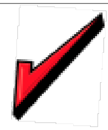
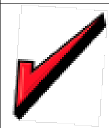
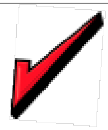
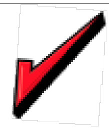
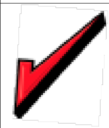
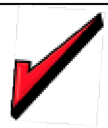
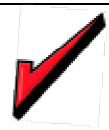
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
The immediate challenges these people faced were not geopolitical but intensely local; for instance, to open a jammed door, navigate a flaming hall way, or climb dozens of flight of stairs. Occupants had to care of themselves and those around them......... *Dwyer and Flynn (2004, p.xxi)*	102.1	 Person coping for themselves	 A culture of coping was to help others – altruistic.	 Stair width was resultant criticism	 Management unable to help
Aviles worked for the Port Authority. He dialled five numbers leaving identical messages, describing what he saw and telling everyone up the chain of command to begin the evacuation....Recount of statement by Aviles (p 18) .	102.2	 Potential was there for everyone to be told but they were not. (*Impact as per 102.1)*	 Breakdown of communication set the culture as per 102.1.		 Communication broke down because of may factors. Instruction not carried through.
Another Broker, George Nemeth, stood between him and the door. Sheehan did not notice him. He ran Nemeth down and kept going....(p.22)	102.3	 No concern	 No concern for a colleague can be evident		

Table A31: Schedule 1 - Comments 102.1-102.3

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
"Start going down the stairs", he ordered. Dechalus turned for the stairway along with the others who had been waiting for the elevators. She (Dechalus) ran into Panigrosso ....(p.22)	102.4	✓ Follows instructions of a warden – superior	✓ Entered stairs as part of a group and met additional colleague in the stairs		✓ Wardens give direct instructions and people follow.
***"**Grab your bag," Yagos said. "We're going" Next to them, Ann McHugh also rose to leave.....(p.24)*	102.5		✓ Group forms on work floor where members work in the same area		
Wardens started to move people towards the stairs.........(p.24)	102.6				✓ Wardens act on own initiative when instructions are unclear.
....they were a human measure meant to make up for what the Fire Department saw as the safety deficiencies in high rise buildings... (conclusion from an interview p.25).	102.7				✓ Perceived value of floor wardens substantiated by 102.6.

Table A32: Schedule 2: Comments 102.4-102.7

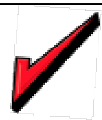
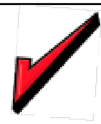
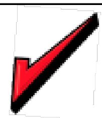
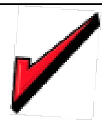
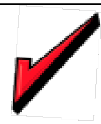
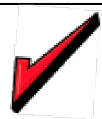
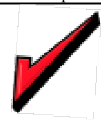
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
With no clear understanding of what was happening Hayes(Deputy fire safety director of the South Tower)was being cautious about giving instructions to the people in the building, Upstairs tenants were proceeding by habit or instinct (p.27)	102.8		 Tenants were making their own decisions in groups – see 102.4.		 Central control did not have full picture so were cautious about letting people evacuate. DELAY
....Many of the people who worked for the bank had been in the building in 1993 so the memory of the calamity ran just beneath the surface......That experience had helped turn emergency preparations into a near religion amongst employees. People learned where the fire stairs were.......One of the banks leaders had sent a memo making their policy clear.....people were the bank's assets...... (p.29)	102.9	 Experience of prior incident	 Employees held common belief about safety – group belief		 Actual corporate commitment to safety and drill practice set scene for a rapid response.
He told an investment banker that he thought the safest place to be was right in the office. But one of his partners, Jace Day, heard Sadler say that anyone who wanted to leave should go.	102.10		 People made their own decisions – groups formed		 GM of Investment bank (Sadler) had experience of 1993 incident – best to wait for central evacuation instructions. Organisation inconclusive.

Table A33: Schedule 3 - Comments 102.8-102.10

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Across the floors of KBW decisions to go or stay were made one at a time. Virtually the entire 88th floor was cleared out. A particular loud investment banker ......swept across the floor yelling at people to leave. *On the 89th floor ....there was less certainty(p.33)*	102.11		✓ Groups comprising different professions or from different departments reacted differently due to safety commitment of leaders		✓ No uniform group culture on evacuation especially with any central instructions.
At a stairway landing on the 27th floor Ed Beyea watched the people streaming past him. He was going nowhere for now. Nothing below his neck moved....The two men had built a solid friendship......They needed 3 or 4 strong men to help.... "I'll stay with Ed".....Find someone downstairs ...and tell them where we are....... (p.43).	102.12		✓ Altruistic behaviour where friend was prepared to stay with the wheelchair bound occupant	✓ There was room in the stairs to accommodate wheelchair and helper on the landing – yet stairs were not wide enough	
Though the shape of the disaster was barely forming in his mind, Thompson knew enough about its scale to pick up the address microphone and order a total evacuation of the building. His message went nowhere......... (p.45).	102.13			✓ Communication system was out so that no messages received on other floors.	✓ Central control convinced to evacuate but communication system was down.

Table A34: Schedule 4: Comments 102.11-102.13

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
In the stairwells, gravity ruled. A firefighters' turnout coat, pants, boots.....weight 29.5 pounds. The mask, and oxygen tank add another 27 pounds ......Firefighters in engine companies also carry an additional 50 feet of hose ...Even though fighting the fire was out of the question, the reflex to bring the gear held....lugged the heavy hose ...into the stairs already packed with people trying to flee.....(p.51)	102.14		✓ People had to stop to let the firefighters past.	✓ Stairs not wide enough for counter flow	✓ Failure to adapt to situation – rescue mode. Added delays and extended evacuation time
Firefighters were still having a hard time using their radios in high rise buildings........(p.54)	102.15		✓ Everyone had to rely on local evacuation instructions.		✓ No boosters for radios so that intercommunication was not possible.
Indeed despite the Trade Centre's status as the city's leading terrorist target co-ordinated evacuation drills were extremely rare events in the life of the complex.(p.58)	102.16	✓ Occupants therefore generally did not practice.			✓ General authority attitude did not promote practice and co-ordination between emergency organisations.

Table A35: Schedule 5: Comments 102.14-102.16

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Thanks to all those drills a group from the Fuji/Mizuho offices on the…..had made it to the lobby of the South Tower nearly as fast as anyone in the building.(p.63)	102.17	✓ People were well practiced	✓ All employees acted in line with their drills		✓ Individual organisation cultural belief – commitment to safety – Ref. 102.9 as well.
"Where are you guys going?" asked the guard asked. ……..”No, no," the guard said. "All is well here. You can go back to your office. The building is secure." For most of the group the authoritative voice of the guard reversed the momentum…….(p.66)	102.18				✓ Evac organisation instructions conflict with people who were more aware of the situation than the guard. Refer also 102.17 and 102.9.
The doctrine – or reflex – of telling people to stay put during evacuations was not universally applied. Seated next to Officer Brady was another policeman, Steve Maggett, who was receiving calls at the same moment. Their advice was entirely different.(p.70)	102.19				✓ Conflicting instructions can change stair entry and use and of course affect safety.

Table A36: Schedule 6: Comments 102.16-102.19

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
The instruction to the caller from Morgan Stanley was especially important. Morgan Stanley occupied twenty two floors and over 2000 people worked for the company. An executive for the bank, Ed Ciffone, had overseen years of intense evacuation programmes, and one of his deputies, Rick Rescorla, had led the drills with a zeal that seemed near evangelical. ... Now it made sense. Their wardens pulled out megaphones and began to drive the Morgan staff out of the building. *(p.72)* *See also 102.19*	102.20		✓ Groups of individuals still in their workplaces received clear instructions and proceeded to the stairs.		✓ Evacuation policy of a major tenant can result in group action.
At the 55th floor, Stephen Miller, hit a logjam in the stairs of the South Tower......he had made reasonable progress from the 80th floor....Now the crowds joining the exodus from the lower floors fell in ahead of them....The delay gnawed at him so he stepped out of the stairway....Then he heard an announcement that the building was secure and that he could return to his office. (p.73). see also 102.19	102.21	✓ Individual is frustrated by delays – causes him to exit stairway	✓ Group of people follow him	✓ Impact of stair width	✓ Conflicting messages causes him and the group to cease evacuation
Along the way Foodlum had tired – she had just finished a challenging chemotherapy series for cancer, and was about to start radiation – but her boss...nudged her along (p.76)	102.22	✓ Condition that increased potential fatigue	✓ Other member of group gently moves her on. Slows group and confirms possibility of risk of individual needing assistance from the group.		

Table A37: Schedule 7: Comments 102.20 -102.22

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
"If anyone needs medical attention, or suffers from asthma, they should go first.....(p.84)	102.23	✓ Individuals who would be slow movers because of their condition or may tire quickly – go first	✓ Example of altruistic behaviour and where decision could place stress on the group because of assistance demands		✓ Letting slow movers go first could be a general policy
The single-minded abandon of Michael Sheehan's departure ....should have carried him clear of the tower by 9:02, but several developments managed to slow him down...When he came across a heavy woman...at the 10th floor, Sheehan ....walked down with her ....out of the building (p.90)	102.24	✓ Young fit individual is an overtaker	✓ Forms group and slows down to assist	✓ Possible to overtake prior to build up of crowds on the stairs	
At the tower's 44th floor sky lobby, Michael Otten waited for the elevator doors to close....they had all but closed when suddenly an electronic sensor read an obstruction and the doors slid open. They reopened again in another maddening cycle....This is ridiculous Otten thought...What's with this guy with the backpack....his luggage was jutting into the light beam and holding everyone up.....(p.91)	102.25		✓ Example of negative group dynamics – impatience. – behaviour not always altruistic – agrees with similar comments from analysis of NY Times Blog example		

TableA38: Schedule 8: Comments 102.23-102.25

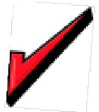
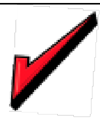
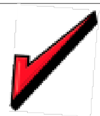
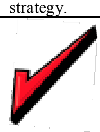
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
This assembly of people had heard three announcements since the explosion in the north tower, two encouraging them not to leave and one suggesting that they could leave if they wanted.....(p.92)	102.26				 Conflicting instructions from central control.
Ling Young.....she and her co-worker...pulled their colleagues....out from the rubble(p.96)	102.27		 Example of group membership comprising co-workers and altruistic behaviour		
They had gone down about three flights (group of five) when they ran into a heavyset woman and a slight man ......he did not take a position on which way they should go but the vehemence of the woman ....seemed to hold sway.(p.98)	102.28		 Interaction with others in stairway can result in changed strategy.		
Clark turned to DiFrancesco ....”Come on, Ron” Clark said. “We got to help this guy”. (p.98)	102.29		 Example of altruistic behaviour – same group as 102.28)		

Table A39: Schedule 9: Comments 102.26-102.29

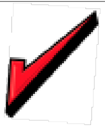
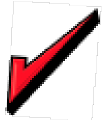
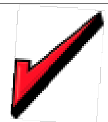
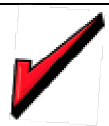
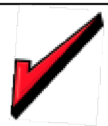
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
... they had given all their strength over to the task of moving and were spent by it.... (p.100).	102.30	 Evidence of fatigue and resting	 Group were actually resting		
He fixed his gaze on the lip of each step; defined by the glow in the dark stripe and started ....he navigated this line down 1512 steps that led from the 84th floor of the South Tower to the lobby... (p.101)..	102.31			 Example of step definition that enhanced wayfinding and safe descent	
COMMENT – Stairway A in South Tower changed position from the 82nd to the 72nd floor to get around plant rooms- caused wayfinding problems for groups of people. Users gradually sorted out the problem. (pp. 112-113)	102.32		 Altruistic behaviour example.	 Example of stairwell footprints where changing positions with long interconnecting corridors can cause wayfinding problems	

Table A40 : Schedule 10: Comments 102.30-102.32

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
In the stairwell, Crown wanted to carry Spera on his back....Reyher said, "That's not a very good idea," pointing out that they still had a long way to go. Spera slung her arms over Crown and Reyher and they began to walk down.(p.115)	102.33	✓ Injured women required assistance slows down group	✓ Altruistic behaviour – help women by supporting her and slowing down.		
Merrero would not be turned back. Vera (his colleague) was in trouble …" I can help him" Marrero said. (p.116)	102.34	✓ Altruistic behaviour and commitment for colleague	✓ Example of an individual turning back to help an exhausted colleague.		
At the 44th floor Clark and Praimnath left the stairs for a break... (p.116).	102.35	✓ Examples of resting – fatigue			
The line moving along the stairs immediately resumed a fast but steady pace...Soloway took the arm of a woman having a panic attack....Salovich carried the bag of another woman hearing about her two children..."Thirtieth floor'" Salovich called out. "It's all downhill from here.(p.118)	102.36	✓ Estimated descent speed – free travel is .47m/sec.	✓ Example of positive group dynamics that helped maintain a steady flow – group can encourage each	**other**	

Table A41: Schedule 11: Comments 102.33-102.36

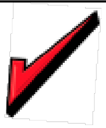
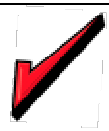
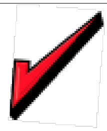
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
….saw the stairs filled with confused people clinging to each other…. (p.119).	102.37		 Example of people relying on each other even with confusion caused by conflicting announcements etc.		
(entry from the 36th floor South Tower)...he found the stairway full and slow…. (p.119)..	102.38			 Stair width causing congestion – due to high volume of traffic.	
The woman used crutches to walk...Torres picked her up on the 54th floor, put her over her shoulder and carried her down to the street.(p.119)	102.39		 Example of altruistic behaviour. Luckily the woman was slight otherwise it may have taken a greater number of people to assist.		

Table A42: Schedule 12: Comments 102.37-102.39

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Louis Lesce wanted to move more deliberately than the people around him. He was 64 years old and had recently undergone a quadruple cardiac bypass. Someone carried his briefcase and someone else carried his coat. (p.120).	102.40	✓ Most likely fear of falling.	✓ Altruistic behaviour where individual assisted by other members of the group.		
....a 58 year old engineering inspector moved from the 82nd floor to the 42nd where he stopped from a break from the heat in the stairwell. (p.120).	102.41	✓ Needed to rest.			
Example of a vision impaired person moving down the stairs with a guide dog....(p.120)	102.42	✓ Vision impairment – using guide dog and group to find way		✓ Group assists vision impaired person.	
.......was having a terrible time breathing because of her asthma.... had to stop every few flights (P. 122).	102.43	✓ Example of asthma and/or dysponea having to stop regularly		✓ Space available for refuge/ rest without holding others up.	

Table A43: Schedule13: Comments 102.40-102.43

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
…..saw Tina Hansen in a wheelchair waiting to go down….. (p.123)..	102.44	✓ Mobility impaired person in an evacuation chair ready to go down – deferred to those in stair for merging	✓ Group ready to assist		✓ Port Authority had organised large numbers of these chairs after the 1993 bombing
The Port Authority's plan for escaping fire did not have a page for roof escape……(p.128)	102.45				✓ Evacuation plan limitations? People still went to roof from higher storeys.
Just as the fire drills made no mention that the roof was not an option… there were no signs in the fire stairs confirming this so that people were not aware of this fact…(p.129)..The roof had been used this way after the 1993 bombing.(p.129)	102.46				✓ Evacuation limitation not notified
Stairway A was clear for the whole height in the South Tower and the command centre knew about it. They could not communicate with the tenants on the upper floors to let them know it was clear.(p.143)	102.47				✓ Communication problems

Table A44: Schedule14: Comments 102.44-102.47

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
They had been efficient...working with a crowbar to free...as if rescuing people was what they had been hired for. ...neither man had a role in the official evacuation or emergency plans for the building. (p.147)...	102.48	✓ Individuals prepared to help – altruistic behaviour.			
Total evacuations are not part of life in tall building in the United States so the plans did not envision thousands of people weaving down the three staircases in each tower.....there were no drills for this (p.168)	102.49			✓ Stair width was an issue for total evacuation.	✓ Total evac not a cre4dible scenario?
When people reached the lobby of the north tower they found that their trip had one more leg...the way out was blocked....instead many people were directed through the Marriott hotel, another building	102.50			✓ Discharge problems	✓ Not included in drills so that central control and wardens had to assist with directions.
Andreacchio in the South Tower managed to communicate with authorities from stairwell on 80th floor and call was logged by 911 team member (p.187).	102.51	✓ Individual can communicate with outside world		✓ No masking of call by structure	✓ Authorities did receive the message as it was logged. Overload hindered response

Table A45: Schedule15: Comments 102.48-102.51

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Palmer had been able to speak over his portable radio in the lobby of the South Tower using the specially designed repeater channel. The (Fire Department) chiefs in the other tower were having no similar success in communicating. (p.188.)	102.52			✓ Similar buildings but construction had different impact on communications	✓ Possible that skill sets of emergency team members varied. (see page 189)
"I've found an exit," he said, and he led them to a door.......She saw a thin man behind her in the stairs........Another colleague, Sankara Velamuri escorted Tembe with his bad knee.... (p.191).	102.53	✓ Example of individual altruistic behaviour leading a group to an exit.	✓ Group comprised co-workers who were helping each other.		
Gentul and Emery had gone up there to lead that group out... (p.194).	102.54	✓ Example of individual altruistic behaviour	✓ Groups had already formed naturally according to work location and relationships		

Table A46: Schedule16: Comments 102.52-102.54

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
A few seconds later, Palmer called Kelly back. The chief apparently had gotten information from people in the stairways..... (p.196).	102.55				✓ Information received about conditions in stairways in the South Tower. Confirms outcome of 102.50.
By the time firefighter Larsen crossed paths with Rescoria all but a handful of Morgan Stanley workers had left the building.... *Observation: Morgan Stanley had 2700 staff located between the 44th and 74th floors (average of 90 persons per floor) so that this is an example of a tenant evacuation team within the total building set up. Refer also 102.30*	102.56				✓ Well co-ordinated efficient tenant evacuation team can lessen the load for external rescue – also provide valuable situational information to emergency rescue personnel.
Devery noticed Young on the 51st floor landing. She seemed ready to faint, but then she launched herself towards the stairs. Dervery exhausted by the climb (51 floors) decided to go down the stairs with her to make sure she got out.... (p.198). Refer also 102.27	102.57	✓ This individual was in pain and yet she drove herself on – sale that had already helped others.			✓ Example of rescue made possible by effective communication as an outcome of 102.30.

Table A47: Schedule 17: Comments 102.55-102.57

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
....one of the first to escape from the upper floor had raced down the stairway A (South Tower) from the 84th floor right out of the building ....As he sat there his...walkie-talkie was capturing transmissions from inside the tower (South Tower)about his colleagues(summary of sentence)......(p. 202)	102.58	✓ Individual had no problems descending through 84 floors.			✓ Example of the outcome of another tenant's rapid response
Palmer called back to the trailing firefighters telling them they should head for stairway A as it was clear......(p.205) *Observation: Palmer is mentioned in elsewhere as one who had sorted out the emergency rescue teams' communication problems. He initiates the use of stairway A for rescue access to higher floors...*	102.59				✓ Emergency Rescue increases firefighter access to higher floors thereby increasing impact of counter flow.
Standing at a window on the 27th floor where she was taking a break from her descent from 88 (North Tower)... she also saw the big man in the wheelchair (Ed Beyea).....(p.213)	102.60	✓ Example of an individual resting after descending 61 floors.	✓ No one had assisted Ed Beyea in the North Tower even although evac chairs were available – negative example of altruism. Refer 102.42		

Table A48: Schedule 18: Comments 102.58-102.60

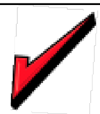
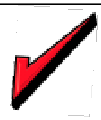
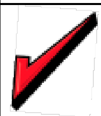
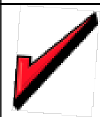
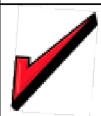
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
...that was part of the ordeal of departure. So, too, were the aches in the feet and the calves, the shimmering heat from all the thousands of people, the dizzying reversals of direction at each landing of the stairs (North Tower)...(P.215)	102.61	 Eccentric muscle conditions in lower limbs confirmed by increased length of descent		 Confirms impact of stair layout in terms of number of turns per storey.	
Fact: The North Tower comprised 3 sections; the lower section up to floor 43, the middle section from floor 44 to 78 and the upper section from 79 to the roof. Comment: By 10:01am the middle section had all been evacuated. People were still proceeding down the stairway in the lower section........ (p.216).	102.62			 Even with the reduced width of the stairways and the number available 34 storeys of the building had been evacuated.	 Emergency personnel were told to clear the North Tower as the South Tower had just collapsed. High level of commitment.
No matter how many times the police dispatcher repeated that message (that North Tower was about to collapse) none of the firefighters in the North Tower ...had radios that could hear these reports... (p.223)..	102.63			 Construction obstructed transmission in part.	 Lost communication. Slowed down rescue. See 102.50 where team member solved the problem. Solution not relayed to South Tower teams.

Table A49: Schedule 19: Comments 102.61-102.63

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Staying put was the official policy in a crisis....Although the Port Authority had changed their minds by 9.00am and ordered a full evacuation the massage had not reached Hoey and his colleagues (on the 64th floor).. They established contact 87 minutes later and started to evacuate... (.p.224).	102.64		✓ Group dynamics on floor where no one questioned policy – negative outcome.		✓ Inflexible company policy to cater for changing scenarios.
*(North Tower) Reese had severe asthma. Everything about the long descent – the heat, the anxiety – tightened the clamp around her throat....her colleague tried soothing assurance, pep talk, pleading... only 5 floors to go and they would be out of the building...**she had to sit.** (p.228)*	102.65	✓ Condition of asthma can completely immobilise even when the end is in sight.	✓ Altruistic behaviour made no difference	✓ Evacuation distance coincides with physical effort. Asthma dysponea reduces the capacity to cope with additional effort.	
(North Tower) By 9.59 the evacuation had slowed to a trickle....9some 72.5 minutes after impact. (Conclusion)	102.66				✓ Even problems with emergency rescue communications response over mid section of building handled by occupants with limited external co-ordination

Table A50: Schedule 20: Comments 102.64-102.66

NY Times Blog (Parker-Pope, 2008)

The outcomes of the Content Analysis of the NY Times Blog facilitated by Parker-Pope (2008) mainly focus on responses of interested parties on the notion that people may not be fit enough to survive in emergencies or undertake the physical challenges involved (e.g. going down multiple flights of stairs) as well as their attitudes to others who are not fit and those who may be vulnerable in this area.

The nature of the NY Times Blog is described elsewhere in Chapters 3 and 4. Taylor Parker-Pope (2008) facilitated the session and allowed free responses on a set theme on fitness to survive an emergency and community attitudes associated with the issues involved. The responses from the Blog were numbered NY1 to NY154 together with the comments made during the session by the facilitator. The procedure could be challenged but Parker-Pope's comments have been taken by the author as being prompts being similar to those permitted in focus group sessions (Krueger and Casey, 2000). The positioning of the facilitator's comments relative to the responses is shown in Table A51 below:

NY COMMENTS 1 - 23
TPP comment 'A'
NY COMMENTS 24-30
TPP comment 'B'
NY COMMENTS 31-37
TPP comment 'C'
NY COMMENTS 38-39
TPP comment 'D'
NY COMMENT 40
TPP comment'E'
NY COMMENTS 41-61
TPP comment 'F'
NY COMMENTS 62-64
TPP comment 'G'
NY COMMENT 65
TPP comment 'H' – MOVING TOWARDS STAIR DESIGN
NY COMMENTS 66-72
TPP comment 'I' – DRAWS THE FIRST CONCLUSION ABOUT STAIR WIDTH
NY COMMENTS 73-102
TPP comment 'J'
NY COMMENTS 103-141
TPP comment'K'
NY COMMENTS 142-154

Table A51: Ordering of NY Times Blog Respondents' and Facilitator's Comments

Table A53 to Table A83 comprise schedules NY 1-30 which show that there were:

- 60 abstractions from the actual document (including a selection of NY Times Blog comments between NY1 – NY154).
- 43 coded as "You", 41 as "Group", 19 as "Stairs and 41 as "Management".

The above details are further disseminated in Table A52 below

Core Consistency	Number of Codings	Percentage of Total Codings		Percentage of Total Abstractions	
You	43	43/144	30%	43/60	72%
You & Others	41	41/144	28%	41/60	68%
Stairs & Construction	19	19/144	14%	19/60	32%
Management & Maintenance	41	41/144	28%	41/60	68%

Table A52: Frequencies of classifications against core consistencies (NY Times Blog)

The percentage of total abstractions shows that the main core consistency was "You" followed by "Groups" and "Management" and then "Stairs", even with the prompting by the facilitator in her comments NY"H" and NY"J". This may be expected given that comment NY"H" was made after 74% of the NY responses had been received and recorded.

"Management" comments mainly involved suggestions by respondents that wardens should organise trial evacuations so as to avoid blockages that they should become more involved in planning for those who are either unfit or have limiting functional limitations, and that trial evacuations are important.

“Group” comments were mixed. The main thrust of the “Group” comments is summarised below:

- Altruistic behaviour would be expected (assisting others) although many comments were the opposite where the person concerned was prepared to penetrate the group’s territory in terms of overtaking.

- Group dynamics where there would be members who would not be prepared to co-operate and would not tolerate slow movers.

- Firm leadership where the good of the group would be seen as paramount.

- Physical implications to and risk for members of the group in assisting others e.g. lifting or supporting morbidly obese persons[5].

- Expectations of aggressive group behaviour.

- Awareness of stress behaviour where slow movers are involved.

- Reference to the source of group members such as fellow workers from same department.

- Reference in quite a few comments to the benefit of group “leaders” with prior evacuation experience.

Comments applying to the core consistency “You” were also a mix. There were a few individuals who even with functional limitations, had learnt through practice and “willpower” to use handrails for support and marshal their neural balance control and movement system (Horak, 2006) to

[5] Substantiated also by Heuer et al (2011) and Puhl and Brownell (2001) in terms of community attitudes and stigma.

go down the stairs. It is here that the provision of rest areas would be important (also reflected in later comments that stairs should be wider). There were some who reflected a level of intolerance. Respondents realised the importance of fitness but were diverted by the internal debate on the possible stigma associated with obesity[5]. Respondents recognised that many moved slowly because they had a fear of falling or lack of confidence. An example is provided of an unfit and obese respondent who could only cope with between 5 and 10 storeys and another who would have not been able to cope with 30 storeys even with rests.

Finally the number of comments referring to "Stairs" centred on the width of the stairs. This core consistency only accounts for 14% of the selected responses. It mainly relates to individual contentions that:

- Space would be provided for slow movers to rest.
- There would be space between group members for others to overtake by passing between so that group territory was not seen as an issue[6].

Unlike the analysis of 102 Minutes (Dwyer and Flynn, 2004) in the previous section the comments have been summarised as a whole without direct references to individual core consistency comments. This is because of the distribution of comments is more uniform (see Table A52).

The various comments and classification of responses into their relevant core consistencies may be found in the following pages in Table A53 to Table A83

[6] Contrary to findings of Knowles et al (1976)

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE & GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
I'm sure that "slow-moving overweight woman" would be just thrilled to see this commentary. Don't you think she has enough stigmas in her life without being publicly told she was threatening other people's lives?	NY1	✓ Empathic attitude	✓ Reflects group attitude		
Fitness is a necessity for countless reasons, the least of which may be for coping with our daily lives.	NY2	✓ Individual coping – participates in H&S Planning			
Fitness is very important for survival, but obviously, so is clear, non panic-stricken thinking. In fact, the presence of former isn't of any use in the absence of the latter.	NY6	✓ Condition is important but so is attitude	✓ Reflects group participation and provision of aid		
It may sound harsh, Di, but that woman could get rid of the stigma by losing the weight or simply getting in shape. What a thought.	NY9		✓ Possible aggressive attitude in group situation		

Table A53: Schedule NY1: Comments NY1, NY2, NY6 and NY9

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
I'm a fat woman who can go down 27 flights in under 5 minutes (assuming there are no bodies in the way). I worked in a skyscraper and made a point of participating in every fire drill. Most people did not leave their offices during the fire drills. *Your size doesn't matter as much as your willingness to KEEP MOVING and DON'T PANIC in an emergency. If 9/11 taught us anything, don't listen to the people who say "Stay put!" when a catastrophe hits your building. Get out of the building as fast as you can. You can't rely on anyone else to rescue you other than yourself.* *SELF HELPER*	NY11	✓ Commitment although obese condition	✓ Commitment to group and most likely altruistic behaviour. Would be a leader		✓ Stay put attitude – implications for Management where no emergency response plan
I've figured that it is about mental and physical fitness together, not one without the other. *SELF HELPER*	NY12	✓ Total commitment and positive attitude			

Table A54: Schedule NY2: Comments NY11-NY12

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
And Anna, if you don't personally know what it's like to be overweight, you simply don't know what you're talking about (and I say this with understanding, since I was in your position once). Being overweight has nothing to do with lack of willpower or laziness or stupidity or all the other assumptions people who are thin make. It has much more to do with poverty, lack of self-worth, hatred of exercise (often caused by vicious bullying in childhood), the repercussions of decades of cruelty, medical problems, and/or (what is not talked about often) different priorities in life. I gained weight after having to take 'prednisone' for over a year, and I was shocked by how strangers felt they had the right to treat me. *SELF HELPER*	NY13	✓ Obese condition but she still has the willpower - coomitment	✓ Would co-operate in a group situation – altruistic behaviour potential because of empathy.		
If I was alone, my Canadian non-confrontationally polite nature would mean I'd die of smoke inhalation rather than say "excuse me" and slip past her… However… if my kids were with me she better get the hell out of the way, because she'd be a speed bump. Being a parent changes everything.	NY14		✓ Attitude – not prepared to help.		

Table A55: Schedule NY3: Comments NY13 and NY14

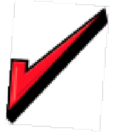
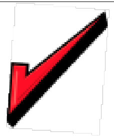
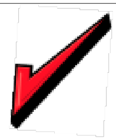
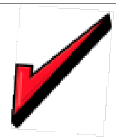
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
..........this isn't about someone's potentially hurt feelings, it's about the clear and important message that an out-of-shape person not only imperils themselves, but puts others at risk around them as well, however unintended. An overweight person's choice to be unfit (passive, yes, but a choice) is their right, of course, but ethics should compel us to aim a little higher than what's minimally required even if it takes some effort or involves a little sacrifice. What greater incentive could there be to drop a few pounds and get exercising?	NY15	 sign of positive empathy so that this person would cope easily.	 Would most likely assist others but still firm to minimise risk to rest of group.		
So let me get this straight, the feelings of the overweight woman are more important than the fact that her inability to move at a steady pace may have potentially cost people behind her in the stairway their lives?	NY16	 Possible ale intolerant person/	 Possible aggressive attitude in a group.		

Table A56: Schedule NY4: Comments NY15- NY16

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Very important for physically limited persons, e.g. seriously overweight, disabled or just being older, to avoid potentially dangerous activities or locales where physical limitations affect safety.	**NY17**	✓ Suggests that individuals should plan for their own safety			✓ Has management implications PEEPS
……….It's not about being fat or thin. It's about being able to do what you need to do to survive and/or help others you love in a dire situation	**NY18.1**	✓ Positive attitude and most likely would help	✓ Importance of group altruistic behaviour		✓ Implies that persons with functional limitations of obesity can hep themselves and the group through PEEPS
. As pointed out by a few people, and wonderfully by Rowan, many people are venturing out into situations they are not prepared to deal with. Did anyone else read that story a few months ago about the several hundred-of-pounds guy who went rafting down a river by himself, had some medical emergency, and took like 5+ people over 8 hours to rescue him? Be whatever shape you want to be, but don't rely on everyone else to rescue you.	**NY18.2**	✓ Accepts that ability is a critical issue	✓ Physical implications of rescue and risk to group		✓ Physical implications of rescue and addressing group risk through evac plan - PEEPS

Table A57: Schedule NY5: Comments NY17-NY18

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
It's not about the weight so much as the fitness............. *When more than half of our country is overweight, doesn't it seem likely that the problem is not with one person's willpower or self-esteem? Perhaps, rather, it is the environment we have all created.*	NY19	✓ Empathy but knows the importance of condition.	✓ Group – altruistic behaviour potential but would most likely appreciate risk of obese person for carrying.		✓ Implications for Management in terms of creating the environment for PEEPS
my sentiments exactly. public health is not about feelings, it's about the facts of safety and those of endangerment. the "slow-moving, overweight woman" in the stairwell did endanger the lives of others, intentionally or not. perhaps this realization would allow most of us to let others pass by us — and, at the very least, to place a priority on becoming as fit as possible.	NY20	✓ As per NY19 but emphasises the importance of condition	✓ Would not impose on a group but still recognises the risk created within any group as per NY19 comment	✓ Implications for providing space for passing	✓ Management implications about catering for evacuation sequence so no blockage – mentions space for passing
Gotta tell you… being significantly overweight might be a choice for some, but there are others that didn't get to make that choice. While a low number of people, there are those that have medical conditions that cause weight gain. Anybody who takes steroids for health reasons will gain weight. I guess their choice is to gain weight to live.	NY21	✓ Condition that cannot be helped - accepting attitude and would be committed to help			✓ Implication for Management? PEEPS?

Table A58: Schedule NY6: Comments NY19-NY21

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
How about just focusing on the 'get exercising' thing and less on the dropping of pounds. It is in fact possible for a person to be strong AND large if that's where her metabolism insistently wants to send her but she also does strength training and some kind of cardio work. She'd probably rather be thinner, for various reasons, and maybe she could get there with additional elements to her program, but this is a topic about emergency fitness so we could limit the discussion to just that.	NY22	✓ Observations on Fitness that pertain directly to an individual's condition relates to strength			✓ Implication for management and PEEPS re people who are not in condition or fit – inclusive approach needed?
if there was an overweight woman / man in front of me impeding a group's escape.....I wonder if it would be possible to have a few stronger big brave Humans to help me carry the woman down the stairs faster.	NY23	Individual is prepared to help but manner would be aggressive	✓ Group implications – carrying the individual – basically altruistic behaviour.		✓ Management learning from trial evacuations – alternative strategic implications - PEEPS

BLOG FACILITATOR COMMENT 'A' - From TPP — an interesting comment that actually proves the broader point of the article. Fitness, particularly strength, is useful in an emergency

Table A59: Schedule NY7: Comments NY22-NY23

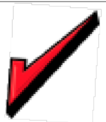
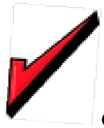
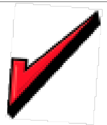
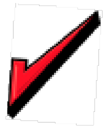
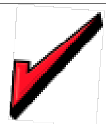
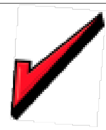
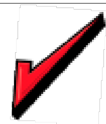
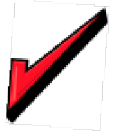
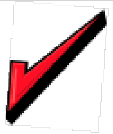
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Obese people have an enormous capacity for rationalization. Also she will probably appreciate the opportunity to revel in her victim-hood. Shame on people for pointing out the problem she caused. After all it wasn't her fault she was overweight and slow-moving. It wasn't her fault she was slowing down the evacuation. *As for Helping Hand and TPP at 5:03 — you really think four (or however many it would take) people carrying an overweight woman down the stairs would clear the jam?*	NY24.1 NY24.2	 Empathy- observation suggests that obese people can be self conscious and positive	 Group implications where group intervention may not solve the problem e.g. not able to carry		 Management Implication?  Implication for Management – alter strategy and PEEPS?
*I'd like to remind folks that, in an emergency, people might not immediately think of what the best way is to proceed, which was, in many ways, the point of the article. ....what about old people, physically-limited people, and other people slowing everyone down... a person stopped completely in a stairwell because they've been knocked over (**or who has fallen**) can make a situation much worse than a line being slow.* *** comment expanded to include fall because of pressure to 'keep up**	NY25	 Other conditions brought up so that condition is the crucial factor	 Assumes others will pushing – aggressive behaviour		 Implies that management should plan so that problems of slow movers are catered for.

Table A60: Schedule NY8: Comments NY24-NY25

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
As someone who has been fat all my life, I would push my body to its limits to get down those stairs, but if I were still impeding other people's exits, I would hope I would have the good grace to get out of the way and let them through.	NY26	✓ Slow mover's comments – she would be prepared to stand aside	✓ Still risk to group where other members would not take "NO" for an answer	✓ Implications that rest spots could be provided	✓ Management needs to plan for resting or alternative strategy - PEEPS
As a fat woman with arthritis, I usually walk downstairs rather slowly......However in fire drills I ignore the pain and MOVE — and my co-workers are amazed at how quickly I get down. *SELF HELPER*	NY27	✓ Positive attitude but potential fall risk?	✓ Group implications are that person could present a fall risk – also as per NY 26.		✓ Management should be aware – potential fall risk? Monitoring?
Being large does not mean that one is weak or out of shape! *SELF HELPER*	NY28	✓ Same as NY 27 re what some obese people can do.- relates to strength as being the main concern			✓ Implications for management – strength vs. condition – use of PEEPS and feedback of drill performance

Table A61: Schedule NY9: Comments NY26-NY28

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
My aunt, who was 85 in November, was in Tower 2 on 9/11. If a pair of fitter young men from her office hadn't helped her down the 50-odd flights of stairs she would have been one of the dead. Should these young men have saved themselves earlier by ignoring my aunt...? The idea behind the show is great-a real-life set of circumstances where the motivation to be in better shape makes sense. The continued and mindless ridicule of the overweight however is rather counterproductive.	NY30	 Stresses importance of individual condition – shows empathy and individual who would help.	 Highlights risk that obese and unfit individuals place on the group because of predominant altruistic behaviour. Also confirms Group altruistic behaviour in WTC 9/11 Incident...		

BLOG FACILITATOR COMMENT 'B' From TPP — I wasn't ridiculing this woman at all. The evacuation was happening two-abreast, but she was so large, nobody could get past her. We had been told burning debris from the attacks had landed on the WFC and we thought the building might be on fire. AS a result, everyone was pretty scared, but thankfully remained calm even though our evacuation was tediously slow because of this woman impeding our progress. Later, once we were out, some men said they were prepared to carry her if necessary. My point was not to ridicule this woman. My point was to impress upon everyone the importance of fitness, regardless of your size.

Table A62: Schedule NY10: Comments NY30

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Two years ago, my building was evacuated for a bomb scare. I work on the 7th floor, and along with two others, have been excused from participating in fire drills for health reasons (heart disease for two of us, knee injury for the other). Of course we chose to evacuate for the bomb scare, and were assigned floor wardens to see we got down safely. Because of chest pain, I stopped on landings several times, out of the way and tried to get people to go past me; there was plenty of room to pass.	**NY35.1**	✓ Self starter prepared to use stairs – fatigue problem -		✓ Rest spot implications that Management would need to take into account	
Well, they wouldn't, and held up others urging me to continue. I appreciated the good will, but for heaven's sake, if someone steps aside, you should either help them or keep going! By the time I got to the bottom, I was able to take the nitro tablets I had, and recover, but I would rather have been left on the stairs than be the cause of others being injured.	**NY35.2**		✓ Group implication – altruistic behaviour confirming NY 26 where group persistence in offering help alters the situation.		✓ Management implications – PEEPS so that resting can be built in to Plans

BLOG FACILITATOR COMMENT 'C' FROM TPP — But the person wasn't hypothetical. She was real. And she slowed the evacuation of many people in a life or death situation. Gender had nothing to do with it, although your point about gender and negative attitudes about fat people is interesting.

Table A63: Schedule NY11: Comments NY35

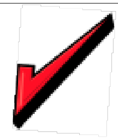
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
TPP's anecdote about evacuating the WFC the morning of 9-11 seems oddly out of place in this article. I don't doubt that it "took what seemed like forever" for Pope "to get out." I'm sure I'd have felt that way in that place on that morning no matter what the pace of the group descending. Fear can do that to you. But, everyone in the WFC did get out, unlike thousands in two other nearby buildings, where fitness had nothing to do with survival for most if not all who died.	NY39		 Comment on attitude – perception of time and onset of stress – See WTC 35.1 & 35.2		
BLOG FACILTATOR COMMENT 'D' From TPP — the people in the WFC were quite fortunate, and I'm not asserting in the slightest that our experience was even remotely similar to the WTC victims. Not very long after I was out of the building and on the ground, the tower fell, the windows in the WFC blew out and the building was filled with toxic debris. Everyone in the building clearly had been at risk, and really, it was thanks to the wisdom of the security guards that we all had enough time to get out. This is not to mention the fact that those of us on the ground had to literally run for our lives to get away from the debris cloud. A friend of mine was blown into the river when the first tower collapsed — it was certainly his high level of fitness that prevented him from drowning. I'm sure there are countless stories from that day where fitness saved lives. But I agree that, tragically, there are likely far more stories from that day where fitness wasn't enough.					

Table A64: Schedule NY12: Comments NY39

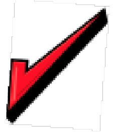
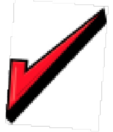
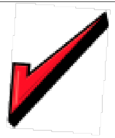
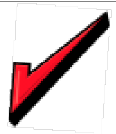
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
So I guess the disabled folks of this world should just have the courtesy to not try to escape, so that all the healthy fit folks can escape at a speed that is more comfortable... And there are many people like my mother, who has multiple sclerosis, and is as a result both overweight and slow. - one in every 1000 people have MS, and twice as many are women than are men.	NY40	 Comorbidity of MS from obesity	 Group implications - altruism	 Stairs in - appropriate	 Management planning and PEEPS
BLOG FACILITATOR COMMENT 'E' From TPP — It's not a judgment or a criticism, it's just a fact. Overweight, out of shape and disabled people are at a terrible disadvantage in an emergency. Hopefully, enough people nearby have a level of fitness that allows them to offer assistance without jeopardizing their own safety. I have a close relative with MS, who is small and frail and would be no more able to evacuate quickly than an overweight person with the condition. it's a terrible disease.					

Table A65: Schedule NY13: Comment NY40

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
I worked in a high rise that was evacuated in the 90s. We were on the 34th floor, and it was agonizing. It was the combination of the crowd, the lack of ability to go as fast as my instincts wanted, and feeling a horrid claustrophobia. But I remember in that situation that the slow people got off on certain floors very much out of a sense of not wanting to slow others down. You could see the "I'm sorry" in their expressions. They were aware, and did the right thing.	**NY41**	✓ Slow Mover due to lack of confidence and pain – they .were altruistic and prepared to rest	✓ Evidence of altruism where other slow movers rested on landings – still the risk of persistent altruistic behaviour	✓ Implications for provision of resting places	✓ Management planning implications – PEEPS which encouraged use of resting spots
Do we always have to do the knee-jerk be-kind-to-fat-people thing? The woman descending the stairs blocking hundreds of others clearly endangered all of their lives. Doesn't matter why she's fat — big bones, slow metabolism, too poor to eat non-fat food, abused as a kid … the facts are that she could have cost many others their lives for no good reason other than her inability to move.	**NY43**		✓ Aggressive attitude that may be typical of others		

Table A66: Schedule NY14: Comments NY41 and NY43

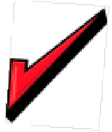
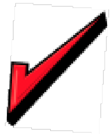
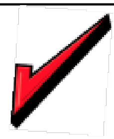
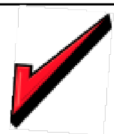
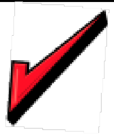
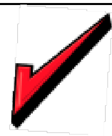
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Yes some people will be slower, weaker, and less able than others. But shouldn't we all strive to be as physically able as possible (accounting for limitations to resources)? There will always be people who need some help due to age or disability. I don't think anyone is proposing that we leave these people behind, but it is the responsibility of these individuals (to the bet of their ability) to know their physical limitations and how to ask for/direct help from others.	**NY48**		 Group implications – accepting that altruism is fundamental		 Management to encourage altruistic group behaviour in training
I'm an overweight woman but have spent a lot of time exercising, eating right, and improving my fitness. There are times when I'm less fit than others, however, I would not have trouble descending (or ascending) stairs, even 10 flights. *I think anyone's bad health could jeopardize others in an emergency. Someone who has low blood sugar could lose consciousness; another person may have panic attacks; yet, another may be in a wheelchair or arthritic and unable to move quickly.........Worse than someone's physical weaknesses, however, may be an uncooperative attitude which could cause problems for the group.*	**NY49**	 Overweight – could cope with 5-10 storeys	 Group implications – altruism but would still place group at risk as per case of NY 26 and negative group attitude may even be a greater threat.	 Implications for rest spots.	 Stresses co-operation – management implication / opportunity – stress positive group attitude and patience.

Table A67: Schedule NY15: Comments NY48-NY49

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
.... there was a woman at my office who was the admin for our division, essentially, who people called "the heart and soul of our office". This woman was very obese, and a smoker to boot. One day she didn't' show up to the office, which was already out of character, and after her second day of absence we found out that she had a stroke. She was 38. She died three days later. 38 years old and she died from a stroke. No previously obvious (as far as her co-workers knew) health problems.	NY51	✓ Obesity and stroke potential risk of co-morbidity in terms of condition	✓ Although no direct comment – group implications re 'heart and soul of the office' comment and therefore the added risk should she require direct assistance		✓ Implications for management to identify this risk and create environment for PEEPS
I was a civilian responsible for any evacuation that might be necessary from the 31st floor of a large Manhattan office building. There was a disabled (or differently-abled) person on my floor who would not have been physically able to walk down the 31 floors in an emergency........I was officially warned against even discussing possible options to successfully evacuate this man unless he started a conversation with me....Since he didn't, I was also enjoined against speaking to anyone else about having a plan to help him escape. *The only thing I could do was to make a plan in my head and hope everyone would cooperate if/when the time came!* *Is this not completely ridiculous?*	NY56	✓ Differently-abled refers to obesity here. 31 storeys too great a challenge	✓ A warden who differed from management which still has group altruistic implications.		✓ Represents possible impact of possible autocratic management attitude. Warden could have facilitated a tenant based PEEPS attitude

Table A68: Schedule NY16: Comments NY51 and NY56

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
There's all sorts of random things like a locked stairwell or a blind person and his dog that slows you down for 20 flights	NY57	✓ Stresses importance of functional ability and need for PEEPS	✓ Appears to accept that group movement rate hinges on slowest mover which is key outcome of altruistic behaviour.	✓ Stairs can be designed to be locked off from the inside denying access back on to floors – no resting place?	✓ Management attitude and practice locking stair doors for security etc.
For me, it's not a matter of fat-bashing or not, but a matter of compassion. Leaving her to slow down others while resenting her for doing so seems like a less useful choice than offering to help her move faster (maybe someone did, and Ms. Pope just didn't mention it?). Her memory of that day may well be, "I was so scared and I was going as fast as I could, but I didn't have anyone I could ask for help and no one offered. I know they resented me."	NY61	✓ Obese – slow mover – not just overweight but other factors as well - biophysical	✓ Group implications – altruistic attitude of 'w e should help' – not always possible especially if insufficient space	✓ From explanation in highlighted dialogue box stairs were too narrow to allow person on either side to support. Importance of resting places.	✓ Implications for management for strategy – PEEPS

BLOG FACILITATOR COMMENT 'F' From TPP — honestly, none of us could conceive of a way to help her. There was really no way to assist her. There wasn't enough room for one person to go on each side of her and help her down. All we could do was stay calm and try not to panic. Had we tried to push past her — and really, we would have had to push as there was no clearance between her and the wall — we could have knocked her over and she would have fallen into the people below her. She and others likely would have been hurt. The situation, as you can see now, was pretty complicated.

Table A69: Schedule NY17: Comments NY57 and NY61

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
It may be the fact that you were slowed by this woman, but it is also a fact, from your description, that the fire stairs were too narrow. I cannot imagine a safe fire escape that is so narrow that no one could pass an obese person AT ALL, even if they weighed 300 lbs. Most fire stairs in modern buildings would easily allow 3 and even 4 ppl abreast (or as someone posted above, room for firemen to go UP.) If someone HAD fallen on these stairs, it would have been as bad as or worse than the obese person, because they wouldn't be moving at all and you would have had to leap over them, apparently. ***I'd say the width of the fire stairs were equally if not more endangering to the majority of ppl. The obese person was an obstruction, plain and simple–the design must allow for a human-sized obstruction, or it isn't a safe design.***	**NY64 KEY COMMENT**	✓ Acknowledges problem of obesity and size – body ellipse	✓ Does not appear to accept group assistance	✓ Stairs are too narrow when compared with latest body ellipse data – raises possibility of other means of evacuation	✓ management should also realise shortcomings of stair design and develop alternative strategies

BLOG FACILITATOR KEY COMMENT 'G' **From TPP — Yes — one of my co-evacuees pointed this out to me this week. He left the experience thinking our stairs were far too narrow. I don't know how old the WFC is or whether stairwell design has changed, but I think you're correct. – 'SETS COMMENTS OFF ON A NEW TACK'.**

Table A70: Schedule NY18: Comments NY64 - Key Comment

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Americans are larger, so stairwells should be too. While it's true that the slow woman was larger than the other evacuees, the situation was largely caused by a too-narrow stairwell. If the stairs had been built 3 abreast rather than 2, the whole issue could have been avoided. Ultimately, it's the design of the building that's most at fault. ***Adds to key comment NY64***	NY65	✓ Adds substance to comment NY64		✓ Adds substance to comment NY64	
BLOG FACILITATOR KEY COMMENT 'H' From TPP — Somewhere in this string is another comment from another reader who raises the same excellent point. Agreed.					
I am impressed by the thoughtfulness and depth in these comments. I was in an 8 story building recently that was evacuated because of a bomb threat. There were so many people descending the stairs, that it is a wonder we all made it out by the time deadline: most of us simply went to the front stairwells, forgetting that there were back stairs for use, because the building does not permit public use of the stairs, except for emergencies. There were people who were walking very slowly in front and few seemed to take it all seriously.	NY66		✓ Group implications where many do not take trial evacs seriously.	✓ Stair design should have encouraged public use	✓ Implications for Management commitment to allow use and promote drills so that people would be familiar with these additional stairs.

Table A71: Schedule NY19: Comments NY61 and NY66.

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Slower people who somehow manage to get ahead of faster ones should stop at the first landing and let others pass.	NY67	✓ Resting implications	✓ Group implications where a group could expect slow movers to step aside – non altruistic behaviour	✓ Implications for the provision of wider landings for resting and allowing others to pass.	✓ Management implications for strategy where resting places not available – PEEPS.

BLOG FACILITATOR KEY COMMENT 'I' From TPP — Yes I realize this is confusing the way I wrote it…..It was a two-abreast evacuation. The slow people were on the right the fast on the left…so there were a few slow people in front of her as well but nobody was impeding her. She was just blocking our ability to move past her so we could exit quickly …. If we had tried to pass her, she would have just fallen down the stairs into other slow moving people…There was no good option for anyone, including her. I think the best point made here is that the stairwell wasn't a safe emergency exit given how little room there was to manoeuvre. Had fire rescuers tried to make their way up, it would have been difficult.

Table A72: Schedule NY20: Comment NY67

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
When I wrote my original post I deleted a reference to an excellent book called "102 Minutes" which is about what happened inside the WTC after the planes hit and before the buildings fell. The book provides detail about hi-rise building codes and how the weakening of many safety regulations, such as mandating an adequate number of stairwells wide enough to accommodate a safe evacuation for the thousands of people those buildings were built to house, was a huge contributing factor to the problem, as it has been in other buildings too. When we had a fire in my hi-rise last year, I was appalled, but not surprised, to find myself going down 23 flights of very narrow stairs at a snail's pace. Maybe you have to be in a situation like that, breathing smoke, to understand the survival instincts that begin to override your humanist ideals in the actual situation. One of the firemen told us there was no way the building could have been fully evacuated using the stairs if the fire had been more extensive. A big part of the problem is indeed the value of sellable space over safety. Stairwells are too few and too narrow in most commercial high rise buildings built after 1960 throughout the US. The example 102 Minutes gives is how much more adequate (and solid) the stairwells are in the Empire State building versus most modern hi-rises. ***REFER ALSO TO COMMENT NY64.***	NY75 KEY COMMENT			✓ Obvious implications for design. Wider stairs is one answer but what about the impact of the group if someone falls. Wider stairs may not solve this. Resting places or elevator evacuation are other considerations may be feasible.	✓ Management implications to develop other strategies where stairs are extremely narrow

Table A73: Schedule NY21: Comment NY75

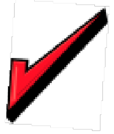
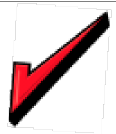
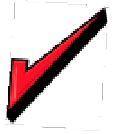
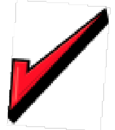
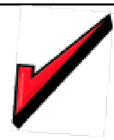
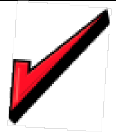
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
Was being slow a direct effect of being overweight? Or perhaps she had a recent fall and her legs were not as strong as they used to be. Maybe she had bad knees and the weight gain was a result of this.	NY79	 Raises the good question of co-morbidities			 Implications for management in planning - PEEPS
Scenario 1 - *the large lady stays on the stairs, and doesn't step aside on the first landing she comes to allow many of the faster people behind her to pass. Firefighters and emergency personnel rushing up the stairs meet her, but cannot pass, and must wait for her to finish exiting the stairwell. She makes it out of the building, but possibly hundreds of people behind her who could have made it out safely perish........* ***Scenario 2 -*** *the large lady steps aside on the first landing she comes to, and, realizing she is preventing other people from escaping, allows many people to step by her. Unfortunately she perishes, but hundreds of lives were saved by her action.* *You obviously support scenario #1. You view that situation as one that embodies "humility and compassion". I guess her one life was more valuable than the hundreds of other lives behind her.*	NY84	 Two interesting scenarios – two possible actions due to condition of obesity and lack of strength.	 Implications for possible impact of altruism where group assisting would have slowed others anyway. Altruism includes understanding and being calm.	 Provision of resting places or perhaps wider stairs that do not compromise counterflow	 Implications for management planning – PEEPS.

Table A74: Schedule NY22: Comments NY79 and NY84

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
If I were in that "stairwell" situation, yes I would help the people I could to escape. But if I were personally slowing up the escape of hundreds of people behind me, I would get out of the way, even at the risk of my own life. Because I don't think my one life is more important than the lives of the hundreds behind me.	NY86	✓ Suggested action of stepping out of the way – altruistic action	✓ Implications for Group – altruism.	✓ Provide resting places or wider stairs- implied	✓ Management should develop strategy. to compensate
The part about the women impeding their exit was actually very telling. New Yorkers are usually considered more rude and pushy, yet under this circumstance they did not run her over, but actually waited.	NY92		✓ Some are surprised at altruistic group behaviour		
As an older disabled woman I would like to direct your attention to the cruise ships where people are asked to self designate themselves as a person who would need assistance in an evacuation. The staff then documents that and sends assistance to the stateroom in case of an emergency. The disabled person knows to return to their stateroom and takes themselves out of the mad rush for lifeboats. Theoretically. *KEY COMMENT FOR MANAGEMENT*	NY100 KEY COMMENT				✓ Key comment for management on self designation – follow maritime practice on cruise ships - PEEPS

Table A75: Schedule NY 23: Comments NY86, NY92 and Key NY100

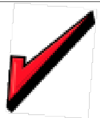
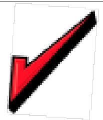
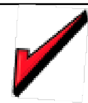
COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
If the stairway crowd had their act together they would have pick up the heavy woman and increased ALL their speeds in the rush to safety. The first thing forgotten in these situations is your fellow man/woman, the inculcated genetic response is to get out NOW and think about it later. When you can assist a group or individual that seems to be hindering everyone it benefits all the escapees, instead of causing a confrontation that dooms the back half.	NY102		 Represents attitude of others with evacuation 'experience' and showing perceived advantage of altruistic behaviour?		 Same attitude could prevail in management and planning may reflect this?
BLOG FACILITATOR KEY COMMENT 'J' From TPP — Sorry, i was there. This woman was too wide. Nobody could stand next to her and assist her. There wasn't enough room. The real issue, upon reflection, is that stairway was too damn narrow for a safe evacuation, and several posters have suggested.					
During the blackout in August 2003, I had to descent 20 flights of stairs in my office building. The stairwell lighting failed, too, so we had to do it in the pitch dark, for the most part, although the lights flickered on for 20 seconds or so every minute or so. Surprisingly, one of the senior managers in the building was encouraging everyone to run down the stairs while the stairwell was lit - what a potential disaster if anyone tripped and fell. I tried to encourage management later to try having "small scale" drills in the dark, so people were prepared	NY104				 Implications for management to have a grasp of safety and be prepared for all situations – maintenance extremely important for safety

Table A76: Schedule NY24: Comments NY102 and NY104

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
I was in a burning building in the late 80s. In the basement trying to get out with several other people. The smoke was choking, my heart was hammering and my mind was yammering "GET OUT!!!" *It was but 2 flights of stairs to safety. I, as a relatively fit individual, stifled the panic for a moment. There were 2 people that needed assistance getting up the stairs. One was an office mate, overweight, and in her twenties. The other, from another suite was in her sixties arthritic but lightweight. I chose the elderly lady piggy-backed her out because she was someone that I could help get out and that would allow me to survive as well.* *My office mate did not make it out.* *There are times to this day when I second guess myself about my actions. I still remember my office mate's eyes…*	**NY110**	✓ Shows implication of condition in terms of being able to be assisted	✓ Selective altruism but small time scale Not only obese but this demonstrates amount of resources that may be required to help an extremely large person.		

Table A77: Schedule NY25: Comments NY130

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
If you're already carrying a lot of extra weight, it's as if you're carrying a heavy backpack; it's hard on your knees and generally slows you down. As the example above shows, obesity inhibits one's ability to preserve one's life in an emergency.	**NY114**	✓ Acknowledges instance of co-morbidities – knees.			
Posters 64# (NY64 key comment) and #65 (NY65 comment) correctly observe that the stairs were simply too narrow for their designed purpose. And following on from Rowan's excellent observations at #3, the safety officer for the WFC should have known that. Taking the premise of his or her job to its logical conclusion, if he or she had done his or her job properly, none who was disabled in any way should ever have been allowed to enter the building because of the difficulties of evacuating such a person.	**NY116.1**			✓ Stairs too narrow for current body sizes – design implications?	✓ The right of access ties in with evacuation – suggestion for management? Discrimination?
The problem of course in the USA is that buildings are so ridiculously high that it's almost completely impractical for most people to use the stairs to go up anywhere near the top. Again, there is a solution albeit radical - do not inhabit such monstrosities. Refuse to shop in them; refuse to work in them; refuse to live in them. Be aware that if the day comes that you have to get from the top of such a building to the bottom in a forced evacuation, and then you may well not make it.	**NY116.2**			✓ High rise is a problem – we create our own problems?	

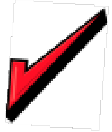
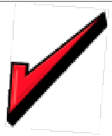
Table A78: Schedule NY26: Comments NY114 and NY116

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
A story recently aired on National Public Radio, and said that people incapable of descending stairways (because of obesity and disabilities) pose so much of a risk to others being able to evacuate safely that fireproof elevators are increasingly becoming the evacuation route of choice at many high-rise buildings:	**NY121**	✓ Obese persons a risk – falling or spatial or fatigue? Complex question.	✓ Complex question but reflects attitudes of a large section of the community – don't place onus on others when design can answer the question.	✓ This alternative is being considered as reflected by the radio presentation	
Here's my very meagre contribution: we aren't sheep –analyze everything. For example if the emergency stairwell lights fail and you have to make your way in the dark do you know how many steps there are per landing and how many landings? ***Do you treat the drills as if they were actual emergencies and do you evaluate the plans that others have laid out for you?..........****There was a high-rise fire in Chicago a few years back in which people died of smoke-inhalation after getting trapped in a stairway that filled with smoke. Knowing this I tested the doors in my building during a drill. By NYC law at least one floor in five is supposed to have doors that allow regress, but none did. (If the doors had functioned as required anyone who felt they were obstructing others could have stepped out of the stairwell all together or those feeling slowed could switch to another stair*	**NY123**				✓ resounding implications for management re education in terms of value of evacuation drills and the state of the stairs that could impede safe evacuation

Table A79: Schedule NY27: Comments 121 and NY123

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
I am middle-aged, handicapped, use a chair, can walk only with extreme difficulty, and am now overweight due to medications. As my mobility has changed, so has my vigilance. I avoid situations that may impose dangers I am not physically prepared to handle. I plan ahead on everything, and carry things that enable me to face ever changing challenges to my health and safety. ....As for escaping, If I can reach a rail, I can fly down stairs faster than the able bodied. If you are arthritic, as I am, turn around ... and walk/hop/hobble backwards while leaning on the rail. It's easier/faster and much less painful for some handicaps then trying to go down facing forward. With the aid of someone to steady you, it's even easier. If I EVER thought my disability was a danger to the survival others I'd get out of the way. I cannot fathom that that woman did not get out of the way. The only thing worse than dying in a smoke filled collapsing building would be knowing that I was in some part responsible for keeping countless others behind me from reaching safety. *SELF STARTER*	**NY127**	✓ Evidence of co-morbidities of obesity and arthritis – positive attitude that he can help himself but it involves a change in stance – the value of involving the individual in PEEPS.	✓ Could rely on the help of another – requires altruistic group behaviour – is there a fall risk? If altruistic then would accommodate alternative gait.	✓ Importance of double handrails – evidence of a user who advises that rails will speed up evacuation.	✓ Change from normal stance and question of potential fall risk – Management implications – PEEPS would be a positive thing here and also linking with handrail provisions in the stairway where there is usually only one handrail.

Table A80: Schedule NY27: Comment NY127

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
.what ever happened to common decency? Two years ago, I was in Atlanta on the 29th floor of a skyscraper when the fire alarm went off...for real. I and a co-worker were able to come down the stairs and get out of the building easily. But the heartbreaking part was that at each landing, the building's security people had pulled aside people in wheelchairs, people that were old, people that were overweight and had mobility problems, as the rest of us descended to safety. Are we now saying that only the fit deserve to survive, or should the fit as a matter of human responsibility stay behind and take care of those that are not as fit...including the overweight?	NY137		 Illustrates the polarisation of attitudes		 similar management strategy to that in part of the WTC1 evacuation – trials vs. actual emergencies

BLOG FACILITATOR KEY COMMENT 'K' FROM TPP — but of course, we didn't push her, but none of us was prepared to help her either. There was no room in the stairway. The real issue, obscured in this discussion, is that stairwells need to be wide enough so that when people do need assistance, there is enough room for people to help them.

Table A81: Schedule NY28: Comment NY137

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
The slow moving, overweight woman was indeed a person who also needed to get out of the building but she has to take responsibility for her condition and not imperil others. *There were numerous stories of others in similar condition who not only did not get out of the Twin Towers alive, they condemned others to a similar fate and all because they refused to take responsibility for their own condition and to do something about it before it was too late. It is not too late for the rest of us.*	**NY144**	✓ Slow movers associated with obesity should be encouraged to self designate	✓ Reflects prevalent attitude of others but the point of taking responsibility for one's condition is made – still a sign of a concern for others.		✓ Implied opportunity for PEEPS where people do take responsibility for themselves
First, while the HR rep at my company was correct to warn me against blocking others on the stairs, the company should have had a plan for evacuating the handicapped, of which I was not the only one. *And second, I am aware that my own fitness could someday be a matter of life and death, preferably only my own. For that reason, I try to avoid situations where my slowness could endanger others.*	**NY146**	✓ He is a slow mover prepared to make alternative plans.			✓ Implications for self designation for PEEPS

Table A82: Schedule NY 29: Comments NY144 and NY146

COMMENT	REF NO.	PERSON/ CONDITION	OTHERS (ATTITUDE AND GROUP IMPLICATIONS)	STAIRS DESIGN SUGGESTIONS AND CRITICISM	MANAGEMENT AND OTHER
I am moderately overweight, but not enough to block others on a stairwell going down. What WOULD block others is that due to accidents (loss of a ligament in one knee from an onstage fall and the other leg full of metal hardware) I have severe degenerative arthritis in both knees which losing 65 lbs, arthroscopy and physical therapy did not cure. I have plenty of stamina and upper body strength due to lifting weights, but I'd need to hold on to one or perhaps both rails to make it down without my legs going out from under me–pain would be irrelevant,	**NY152**	✓ Degenerative arthritis obviously hampers descent – has some strength so that handrails are vital – shows that other conditions or co- morbidities can Severely impact descent ability		✓ Supports absolute importance of double handrails	✓ Management strategy in use of self designation and PEEPS

Table A83: Schedule NY30: Comment NY152

A6.4.3 Core Consistency Detailed Coding used in Content Analysis

Generally

The core consistencies of "YOU", "YOU & OTHERS or GROUP", "STAIRS" and "MANAGEMENT" have been coded in further detail based on the direction taken within each core consistency from the summaries in the Schedules. The purpose of this is to provide a greater breakdown of the profile of each consistency which is based on the detail provided by the Delphi Group in Section A6.3. Code names reflect the direction of the intent of the comments and opinions under each core consistency and also line up with the intent of the Delphi Group opinions. The framework is based entirely on the outcomes of the content analysis, and Delphi group sessions and as summarised in Figure A28 below:

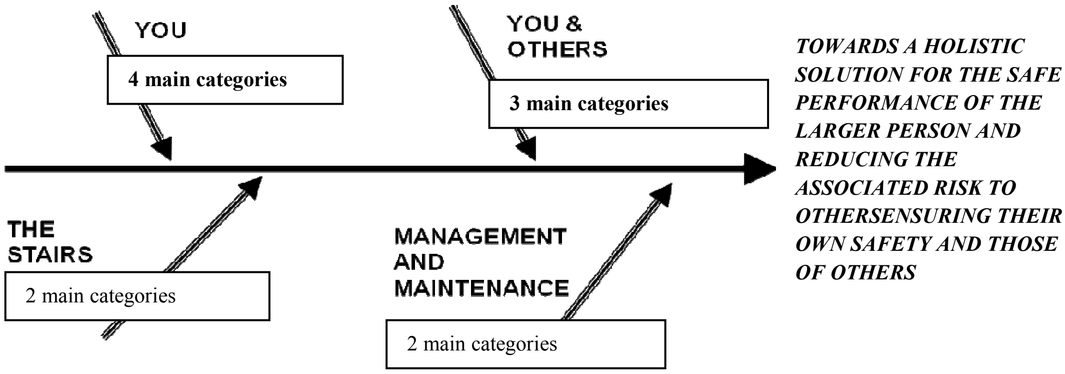


Figure A28: Classification Framework of Core Consistencies and Coding Categories

It should be noted at this stage that the coding categories are intended to provide some direction within the core consistencies in line with the intent of Hsieh and Shannon (2005). Focus Group comments are only coded within their core consistencies as the comments are specific and relate directly to the individual making them. If the same category coding regime was to be applied to the Focus Group comments then some of the "richness" of the data would be lost that is unique to those the Fuller Figure and Mature Age Groups.

The Category Coding Regime follows below:

Core Consistency: "You" (The Individual)

Condition (YC)*

- Obesity (YC1).
- Fitness (YC2).
- Strength (YC3).
- Co-morbidities affecting stance and gait (YC4).

Behaviour (YB)*

- Aggressive or non-altruistic – demand help from others or non self starter (YB1).
- Altruistic – would not slow others down (YB2).
- Readily accept assistance and risk (YB3).

Mental attributes and determination (YM)*

- Have condition and will help themselves – willpower (YM1).
- Decisiveness (YM2).
- Other – Attitude (YM3).

Spatial and Experiential (YS)*

- Awareness of space required to assist/ to pass/ to rest (YS1).
- Previous drills/ building element knowledge (YS2).

** Sub category coding within each core consistency classification*

Core Consistency: "YOU AND OTHERS"

Group Dynamics and Capacity to Assist (OGD)*

- Cohesion and commitment (including territory) (OGD1).

- Altruism and assisting (OGD2).
- Risk of actions associated with assisting (OGD3).

Risk factors (OR)* Aggressive or intimidating action that may place other members of the group at risk including falling.

Group knowledge/ commitment (OGK)*

- Building element knowledge (OGK1).
- Way finding / experience of previous drills as group (OGK2).
- Level of training to assist (OGK3).

** Sub category coding within each core consistency classification.*

Core Consistency: "Stair Design, Construction and Environment"

Stair width and refuge (SS)*

- Stair width and layout (SS1).
- Number handrails (SS2).
- Refuge - Place to rest that will not hinder flow (SS3).

Obstruction (SO)*

- Element of obstruction that interferes with or prevents evacuation (e.g. locked doors)n (SO1).
- Equipment defect that affects flow such as illumination, no ventilation, other. (SO2).

** Sub category coding within each core consistency classification.*

Core Consistency: "Management and Maintenance"

The categories are coded as follows:

- **Central Organisation:** preparedness/ resources/ policy/ commitment/adaptability/ decisiveness culture/ currency/ experience. Includes negative and positive aspects. (MC)*.

- **Tenant Organisation:** preparedness/ resources/ policy/ commitment/adaptability/ decisiveness culture/ currency/ experience. Includes negative and positive aspects (MT)*.

** Sub category coding within each core consistency classification. No mention made of Maintenance in either of the Studies*

Summary of Core Consistency Coding

The frequencies of the categories under each core consistency are shown below:

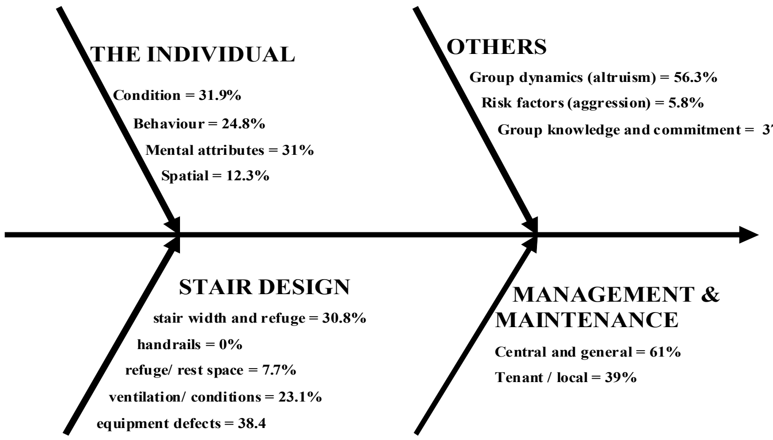


Figure A29: Ishikawa Chart - Summary of internal categories coded against each core consistency – 102 Minutes (Dwyer and Flynn, 2004)

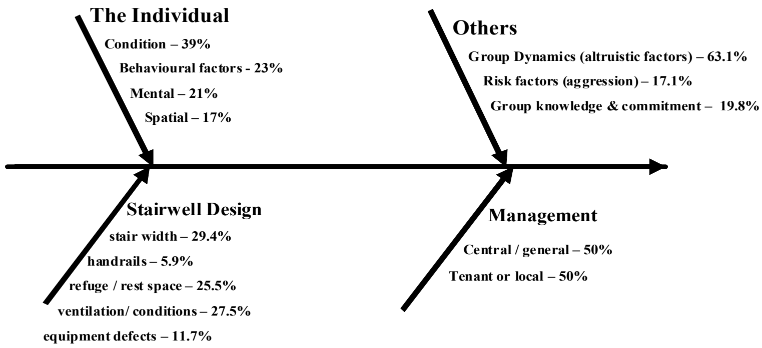


Figure A30: Ishikawa Chart- Summary of internal categories coded against each core consistency- NY Times Blog (Parker-Pope, 2008)

The direction provided by the internal analysis of each core consistency is discussed in the next section.

A6.4.4 Analysis of Content Analysis Studies

The allocation of the internal categories for each of the core consistencies for both “102 Minutes” (Dwyer and Flynn, 2004) and “NY Times Blog” (Parker-Pope, 2008) is shown in Table A31 to Table A50. The output from these tables is summarised in Ishikawa Charts for each of the analyses in Figure A29 and Figure A30. The direction provided within each core consistency of two different studies are then compared.

	CONDITION				BEHAVIOUR				MENTAL ATTRIBUTES /WILLPOWER			SPATIAL AND EXPERIENTIAL	
REF NO.	YC 1 Obesity	YC2 Fitness	YC3 Strength	YC4 Co-morb.	YB1 Aggressive	YB2 Altrusitic	YB3 Assist		YM1 Self help	YM2 Decisiveness	YM3 Other/comms	YS1 Awareness	YS2 Previous drills
102.1		1	1			1	1		1	1			
102.2						1	1			1	1	1	
102.3					1				1	1			
102.4										1	1	1	
102.5						1	1			1	1		
102.6													
102.7													
102.8													
102.9						1	1			1	1	1	1
102.10													
102.11													
102.12													
102.13													
102.14													
102.15													
102.16											1		
102.17						1	1		1	1	1	1	1
102.18													
102.19													
102.20													
102.21					1				1		1		
102.22		1	1	1		1							
102.23		1	1	1			1						
102.24		1	1			1	1			1		1	
102.25													
102.26													
102.27													
102.28													
102.29													
102.30		1	1										
102.31													
102.32													
102.33		1	1			1	1			1	1	1	
102.34						1				1			
102.35		1	1									1	
102.36						1	1						
102.37													
102.38													
102.39													
102.40		1	1	1									
102.41		1	1										
102.42				1									
102.43		1	1	1									
102.44				1			1						
102.45													
102.46													
102.47													
102.48						1	1		1	1	1	1	
102.49													
102.50													
102.51										1	1		
102.52													
102.53						1				1	1	1	
102.54						1	1			1	1	1	
102.55													
102.56													
102.57			1	1					1	1		1	
102.58		1	1		1				1	1		1	
102.59		1	1										
102.60			1										
102.61													
102.62													
102.63													
102.64													
102.65		1	1	1									
102.66													
total	0	13	15	8	3	13	12		7	16	12	12	2

Table A84: "YOU" CORE CONSISTENCY CATEGORY CODING – 102 MINUTES (Dwyer and Flynn, 2004)-*Summarised in* Figure A29

	YOU AND OTHERS							
	Group Dynamics and capacity to Assist			Risk factors	Group knowledge and Commitment			
REF NO.	OGD1-Cohesion & commitment	OGD2 Altruism	OGD3 Risk of Action	OGA1 No altruism	OGK1 Bldg Element Knowledge	OGK2 Wayfinding	OGK3 Level of training to assist	OGK4 Other
102.1	1	1			1	1		
102.2		1					1	1
102.3				1				
102.4	1	1			1	1	1	
102.5	1	1						
102.6								
102.7								
102.8	1							1
102.9	1	1			1	1	1	1
102.10		1					1	
102.11		1					1	1
102.12		1		1				
102.13								
102.14	1	1	1		1	1	1	1
102.15								1
102.16								
102.17	1	1			1	1	1	1
102.18								
102.19								
102.20	1	1			1	1	1	1
102.21				1				1
102.22	1	1					1	
102.23		1					1	
102.24		1	1					
102.25				1				
102.26								
102.27	1	1	1					
102.28				1				
102.29	1	1						
102.30			1					
102.31								
102.32	1	1				1		
102.33	1	1	1					
102.34	1	1	1					
102.35								
102.36	1	1						
102.37		1						
102.38						1		
102.39	1	1	1					
102.40	1	1						
102.41								
102.42								
102.43								
102.44	1	1			1		1	1
102.45								
102.46								
102.47								
102.48								
102.49								
102.50								
102.51								
102.52								
102.53	1	1				1		
102.54	1	1					1	
102.55								
102.56								
102.57								
102.58								
102.59								
102.60			1	1				
102.61								
102.62								
102.63								
102.64	1	1					1	
102.65	1	1						
102.66								
Totals	22	28	8	6	7	9	13	10

Table A85: "YOU & OTHERS" CORE CONSISTENCY CATEGORY CODING – 102 MINUTES (Dwyer and Flynn, 2004)

	THE STAIRS AND CONSTRUCTION				
	Stair Width and Refuge			Obstruction	
REF No.	(SS1) Stair Width	(SS2) Number Handrails	(SS3) Refuge	(SO1) Element	(SO2) Equipment Defect
102.1	1			1	
102.2					1
102.3					
102.4					
102.5					
102.6					
102.7					
102.8					
102.9					
102.10					
102.11					
102.12			1		
102.13					1
102.14	1			1	1
102.15					
102.16					
102.17					
102.18					
102.19					
102.20					
102.21	1			1	
102.22					
102.23					
102.24	1				
102.25					
102.26					
102.27					
102.28					
102.29					
102.30					
102.31					1
102.32				1	
102.33					
102.34					
102.35					
102.36					
102.37					
102.38	1				
102.39					
102.40					
102.41					1
102.42					
102.43			1		
102.44					
102.45					
102.46					
102.47					
102.48					
102.49	1				
102.50				1	
102.51					1
102.52					1
102.53					
102.54					
102.55					
102.56					
102.57					
102.58					
102.59					
102.60					
102.61	1				1
102.62	1				
102.63					1
102.64					
102.65				1	1
102.66					
Totals	8	0	2	6	10

Table A86: "STAIRS" CORE CONSISTENCY CATEGORY CODING – 102 MINUTES (Dwyer and Flynn, 2004).

Table A87: "MANAGEMENT & MAINTENANCE" CORE CONSISTENCY CATEGORY CODING 102 MINUTES (Dwyer and Flynn, 2004)

Figure A29

MANAGEMENT AND MAINTENANCE		
REF No.	Central	Tenant
102.1	1	
102.2	1	
102.3		
102.4		1
102.5		
102.6		1
102.7	1	1
102.8	1	
102.9		1
102.10		1
102.11		1
102.12		
102.13	1	1
102.14	1	
102.15	1	
102.16	1	
102.17		1
102.18	1	1
102.19	1	
102.20		1
102.21	1	
102.22		1
102.23	1	
102.24		
102.25		
102.26		
102.27		
102.28		
102.29		
102.30		
102.31		
102.32		
102.33		
102.34		
102.35		
102.36		
102.37		
102.38		
102.39		
102.40		
102.41		
102.42		
102.43		
102.44	1	
102.45	1	
102.46	1	
102.47	1	
102.48		
102.49	1	
102.50	1	
102.51	1	
102.52	1	
102.53		
102.54		
102.55	1	1
102.56		1
102.57	1	
102.58		1
102.59	1	
102.60		
102.61		
102.62	1	
102.63		
102.64		1
102.65		
102.66	1	1
Total	25	16

YOU "THE INDIVIDUAL"												
	CONDITION	60			BEHAVIOUR	36		MENTAL ATTRIBUTES /WILLPOV		33	SPATIAL AND EXPERIENTIA	27
REF NO.	YC 1 Obesity	YC2 Fitness	YC3 Strength	YC4 Co-morb.	YB1 Aggressive	YB2 Altrusitic	YB3 Assist	YM1 Self help	YM2 Decisiveness	YM3 Other	YS1 Awareness	YS2 Previous drills
NY1						1						
NY 2								1		1		1
NY 6		1							1			
NY 9												
NY11	1							1	1			1
NY12		1						1	1			
NY13	1							1	1			
NY14												
NY15		1				1		1	1			
NY16		1			1		1					
NY17	1	1		1		1						
NY18						1	1	1				
NY19	1	1							1			
NY20	1	1					1		1		1	
NY21	1			1			1		1			
NY22		1	1									
NY23			1			1						
NY24	1					1	1			1	1	
NY25												
NY26	1					1		1	1		1	
NY27	1			1		1		1	1			1
NY28	1	1	1									
NY30				1		1	1					
NY35				1		1		1	1		1	1
NY39												
NY40				1		1						
NY41						1				1	1	
NY43											1	
NY48												
NY49	1	1		1	1						1	
NY51	1	1		1		1						
NY56			1	1		1					1	1
NY57												
NY61	1	1	1	1							1	
NY64	1				1						1	
NY65	1										1	
NY66												
NY67		1				1					1	
NY75												
NY79			1	1		1						
NY84	1				1	1		1	1		1	
NY86						1	1		1		1	
NY92												
NY100												
NY102												
NY104												
NY110			1	1		1	1		1		1	1
NY114												
NY116												
NY121	1		1								1	
NY123												
NY127	1	1	1	1		1		1	1		1	1
NY144	1	1	1		1	1	1					
NY146		1		1				1	1		1	1
NY152				1		1		1	1		1	
Col TOTAL	19	16	10	15	5	22	9	13	17	3	19	8

Table A88: "YOU" CORE CONSISTENCY CATEGORY CODING – "NY TIMES BLOG" (Parker-Pope, 2008).

	YOU AND OTHERS						
	Group Dynamics and capacity to Assist			Risk factors	Group knowledge and Commitment		
REF NO.	OGD1-Cohesion & commitment	OGD2 Altruism	OGD3 Risk of Actions	ONA1 No altruism	OGK1 Bldg Element Knowledge	OGK2 Wayfinding	OGK3 Level of training to assist
NY1		1					
NY 2							
NY 6		1		1			
NY 9				1			
NY11	1	1	1				
NY12							
NY13		1	1				
NY14			1	1			
NY15	1	1	1				
NY16			1	1			
NY17							
NY18		1	1				1
NY19		1	1				1
NY20		1	1				
NY21							
NY22							
NY23		1	1				1
NY24			1	1			1
NY25			1	1			
NY26		1	1		1		
NY27	1	1					1
NY28							
NY30	1	1	1				
NY35		1	1				
NY39		1					
NY40		1					
NY41	1	1	1		1		
NY43			1	1			
NY48		1	1				1
NY49			1	1			
NY51		1	1				
NY56		1	1		1		1
NY57			1				
NY61	1	1	1				
NY64				1	1		1
NY65							
NY66	1		1		1	1	1
NY67	1			1			
NY75							
NY79							
NY84	1	1	1		1		1
NY86	1	1			1		
NY92		1	1				
NY100							
NY102	1	1	1	1			
NY104							
NY110	1	1	1			1	
NY114							
NY116							
NY121		1	1	1			
NY123							
NY127		1			1		1
NY144	1	1	1	1			1
NY146							
NY152							
TOTAL	13	28	29	13	8	2	12

Table A89: "YOU & OTHERS" CORE CONSISTENCY CATEGORY CODING – "NY TIMES BLOG" (Parker-Pope, 2008). ***Summarised in***

	THE STAIRS AND CONSTRUCTION				
	Stair Width and Refuge			Obstruction	
REF No.	(SS1) Stair Width	(SS2) Number Handrails	(SS3) Refuge	(SO1) Element	(SO2) Equipment Defect
NY1					
NY 2					
NY 6					
NY 9					
NY11					
NY12					
NY13					
NY14					
NY15					
NY16					
NY17					
NY18					
NY19					
NY20	1		1	1	
NY21					
NY22					
NY23					
NY24					
NY25					
NY26	1		1	1	
NY27					
NY28					
NY30					
NY35	1			1	
NY39	1	1		1	
NY40	1		1	1	1
NY41	1		1	1	
NY43					
NY48					
NY49			1		
NY51					
NY56					
NY57				1	1
NY61	1		1		
NY64	1		1	1	1
NY65					
NY66	1			1	1
NY67	1		1	1	
NY75	1		1	1	
NY79					
NY84	1		1	1	
NY86	1		1	1	
NY92					
NY100					
NY102					
NY104					
NY110					
NY114					
NY116	1		1	1	1
NY121	1		1		1
NY123					
NY127		1			
NY144					
NY146					
NY152		1			
TOTAL	15	3	13	14	6

Table A90: "STAIRS" CORE CONSISTENCY CATEGORY CODING – "NY TIMES BLOG" (Parker-Pope, 2008)

MANAGEMENT AND MAINTENANCE - 60		
REF No.	Central	Tenant
NY1		
NY 2		
NY 6		
NY 9		
NY11	1	1
NY12		
NY13		
NY14		
NY15		
NY16		
NY17	1	1
NY18	1	1
NY19	1	
NY20		1
NY21	1	1
NY22		1
NY23	1	
NY24	1	
NY25	1	1
NY26	1	1
NY27	1	1
NY28		1
NY30		
NY35	1	1
NY39		
NY40	1	1
NY41	1	
NY43		
NY48		1
NY49	1	1
NY51		1
NY56	1	1
NY57	1	
NY61		1
NY64	1	1
NY65		
NY66	1	
NY67	1	1
NY75	1	1
NY79		1
NY84	1	1
NY86	1	1
NY92		
NY100	1	1
NY102	1	1
NY104	1	
NY110		
NY114		
NY116	1	
NY121		
NY123	1	1
NY127	1	1
NY144	1	1
NY146		1
NY152	1	1
total	30	30

Table A91: "MANAGEMENT & MAINTENANCE" CORE CONSISTENCY CATEGORY CODING – NY TIMES BLOG

(Parker-Pope, 2008)

The two selected studies (Dwyer and Flynn, 2004 and Parker-Pope, 2008) are quite different in that one is the recollection of an actual incident so that it is based on fact and perception. The other is a voicing of opinions that reflect community attitudes and opinions on fitness and emergencies. The analysis in this section will be comparative so that the findings can be tested against the outcomes of the two Focus Groups to see whether any generalisations can be made in line with case study principles (Yin, 2009).

STUDY NAME	THE INDIVIDUAL				YOU AND OTHERS (GROUP)			STAIRS					MANAGEMENT	
	Condition	Behaviour	Mental	Spatial	Dynamics	Risk	Knowledge	Width	Handrails	Rest/Refuge	Conditions	Equipment	Local	Central
102 Minutes	31.9	24.8	31	12.3	56.3	5.8	37.9	30.8	0	7.7	23.1	38.4	39	61
NY Times Blog	39	23	21	17	63.1	17.1	19.8	29.4	5.9	25.5	27.5	11.7	50	50
Total	35.45	23.9	26	14.65	59.7	11.45	28.85	30.1	2.95	16.6	25.3	25.05	44.5	55.5

Table A92: Comparison between 102 Minutes and NY Times Blog Content Analysis Studies

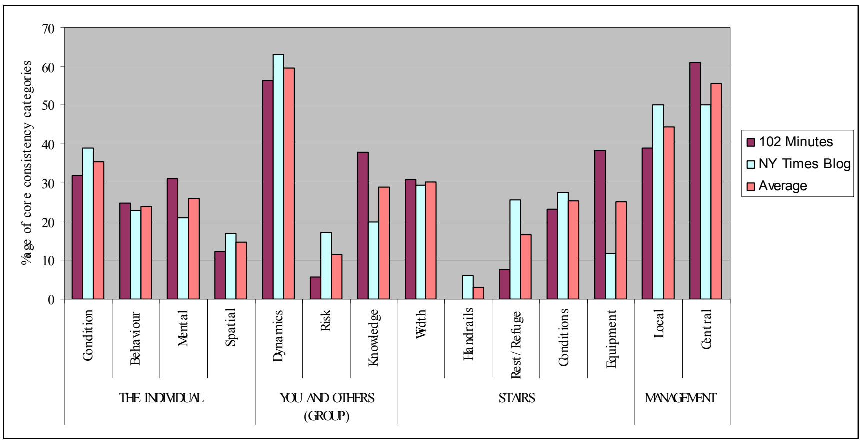


Figure A31: Graph of Category Percentages relative to each Core Consistency

Table A92 and Figure A31 above show some interesting directions within each core consistency. These are discussed below for each study and then as an average across the two studies. There is an internal pattern for each of the core consistencies so that generalisations can be made (Yin, 2009; Hak and Dul, 2009 and Tellis, 1997). It should be noted in this instance that the pattern matching technique is not being used as a means of testing a hypothesis but rather to compare patterns arising out of two disparate studies (Yin, 2009 and Hak and Dul, 2009).

The internal patterns within each core consistency appear from the ordering of the results from each study. Following the results shown in Table A92 the patterns for "You" (Individual) and "You and Others" (Group) are reasonably identical except for the mid range ordering for the Individual.

	102 MINUTES	NY TIMES BLOG	
Category Order			
	You (Individual)		**Comments**
Most	Condition	Condition	
Mid	Mental	Behaviour	*Similar categories occur within the mid range*
Level	Behaviour	Mental	*although percentages differ slightly*
Least	Spatial	Spatial	
	You & Others (Group)		Comments
Most	Dynamics	Dynamics	*Pattern coincides exactly*
Mid	Risk	Risk	
Level			
Least	Knowledge	Knowledge	
	Stairs		Comments
Most	Equipment	Width	*Pattern is slightly different but width is second in 102 Minutes and first in NY Times Blog*
	Width	Conditions	
	Conditions	Risk Refuge	*Mid range differs in terms of order but variances are small*
	Risk/Refuge	Equipment	
Least	Handrails	Handrails	*handrails are the lowest by a clear margin*
	Management		Comments
Most	Central	Central/ Local	*There is no distinct pattern other than a 60:40 split with Central being the*
			most prevalent would not be out of order given that local is normally subservient to central
Least	Local	NA	*organisation e.g. AS 3745-2011 and Dwyer and Flynn (2004).*

Table A93: Ordering of Core Consistency Categories for 102 Minutes and NY Times Blog

The patterns for the remaining two core consistencies, "Stairs" and "Management" are not as consistent. The "Width" category for "Stairs" is the most predominant category for the "NY Times Blog" study and the second most predominant category for the "102 Minutes" study so that there is a weak "pattern" seeing the least predominant factor was "handrails". The latter matches the findings across the eight buildings in the Exploratory Case Study in Chapter 5. Also the statement that stair width is an important issue matches findings of other post WTC 9/11 Incident studies (Peacock et al, 2009 and Blair, 2010). The claim that there is any distinct pattern for Management can be challenged in that there are only two categories centred on the emergency management organisation. There is an even split between local and central roles, procedures and respondent (individual) expectations for the "NY Times Blog" and an approximate 60:40 split for the "102 Minutes" study where Central was the predominant factor because of the role of the Port Authority. Comment 102.20 underpins this factor even where major Tenants (J.P.Morgan) were involved. Although the impact was to have the employees move toward to exits and into the stairs this was still in conflict with some of the instructions being given from the central emergency management organisation (see Comment 102.20 below).

<u>Comment 102.20</u>

"The instruction to the caller from Morgan Stanley was especially important. Morgan Stanley occupied twenty two floors and over 2000 people worked for the company. An executive for the bank, Ed Ciffone, had overseen years of intense evacuation programmes, and one of his deputies, Rick Rescorla, had led the drills with a zeal that seemed near evangelical. ... Now it made sense. Their wardens pulled out megaphones and began to drive the Morgan staff out of the building."
Dwyer and Flynn (2004, p.72). Shows the impact of a committed prepared organisation who was also a large tenant. Groups here were most likely a mixture of work colleagues from a particular department or team and those formed in transit to the stairs following the warden's instructions. The core consistencies involved were "Groups" and "Management". If this comment is read in conjunction with comment 102.19 then the potential conflict can be seen with central management directions.

The most predominant category within the "You" (Individual) core consistency was Condition YC which comprised the following:

- Obesity (YC1)
- Fitness (YC2)
- Strength (YC3)
- Co-morbidities affecting stance and gait (YC4)

Condition YC underpins the aim of the PhD Case Study where the physical challenge of descending multiple flights of stairs is seen as being based on the stair user's or occupant's fitness and strength. Lack of fitness results in obesity (Booth et al, 2002). Lack of fitness combined with ageing will lead to loss of strength especially in relation to stability and to a certain extent in dynamic or aerobic capacity (Reeves et al, 2008). Functional limitations also play a role in the stair user's / occupant's confidence in going down the stairs and are not only mirrored in their descent speed but also the distance they have to travel (Spearpoint and MacLennan, 2012). Other elements from the mid range of categories deal with mental, neurological and behavioural factors which can also affect descent speed and the confidence that people may have that they can complete the challenge (e.g. fear of falling). The latter is often reflected in the degree to which the people rely on the use of the handrail (Reeves et al, 2008a). It is interesting to note the low ordering of handrail use. This reflects the finding of the Exploratory Case Study in that the majority of the respondents did not appear to rely on the handrail for support. Even the support of others does not provide the user with the mental strength and belief in themselves to complete the "journey" (see comment 102.65 of the "102 Minutes" Study).

An interesting comparison required at this point to filter the "You" or "Individual" results is one with the work of Shields et al (2009) on the behaviour and evacuation experience of WTC9/11 evacuees with self designated mobility impairments. One factor that is missing in the "102 Minutes" study is a measure of the respondent's descent speed so as to determine the impact of the functional limitation.

The pattern for "You and Others" is in complete agreement between the two studies and therefore can be generalised across the 2008-2010 case study. The most predominant category is group dynamics. Altruism or, being prepared to assist, is the most predominant element within the "group dynamics" category. The latter corresponds with the findings of the content analysis carried out of media reports by Fahy and Proulx (2005). Cohesion and the risk of assisting others were also considerations but were over shadowed by the preparedness of group members to help others. These two studies did not contain any information about the frequency of group formation as compared with the Exploratory Case Study.

It is important to know where the groups were formed and whether they were primary or affiliate groups. Shields et al, (2009) talk about primary and affiliate groups. The primary group they showed was one formed by an individual with functional limitations who required assistance. The affiliate group is one that can attach itself to the primary group. It is unclear where this attachment is formed. The studies (Dwyer and Flynn, 2005 and Parker-Pope, 2008) showed groups that maintained their membership when they comprised colleagues from the same department, most likely working in the same location. The Exploratory Case Study showed that there was a marked increase in groups formed within the stairwell as opposed to "on the floor".

Cohesion is related to the degree of bonding between the members of the group and one would expect the degree of altruistic behaviour exhibited. This is not the case when one considers the context of "Comment 102.24" from the 102 Minutes Study (Dwyer and Flynn, 2005) where the individual who was overtaking at random stopped when he came across the "heavy" woman on the 10^{th} floor and assisted her through the next 10 storeys. A bond as well as a group was formed. Perhaps groups are transient as argued by Shields et al (2009) so that the context of each evacuation needs to be explored carefully before generalisations can be made. This also applies to the "permeability" of group territory (Lindskold et al, 1976). Permeability needs to be considered with spatial distribution of the members when intrusion by a separate "aggressive" individual typified by certain attitudes in the "NY Times Blog" Study. Comment 102.24 (see below) shows that the heavy woman may or may not have been attached to a group.

The members of the group may not be able to assist but the young man who may have initially classified as "aggressive" was allowed to penetrate the group boundaries and assist the woman (altruistic) behaviour. It could be argued that this man in fact became part of a primary group.

COMMENT 102.24
"The single-minded abandon of Michael Sheehan's departure ....should have carried him clear of the tower by 9:02, but several developments managed to slow him down...When he came across a heavy woman...at the 10th floor, Sheehan ....walked down with her ....out of the building."
Dwyer and Flynn (2004, p.90). Shows that overtaking occurred so that single-minded behaviour may have been initial behaviour but this was placed by altruistic behaviour with the large woman whom he assisted for 10 floors until they were out of the building. The applicable core consistencies are "You", "Group" and "Stairs". Overtaking did occur so that Sheehan may have moved through group territories. A group was formed in the stairs and on other occasions may have slowed others behind as the group would have occupied the stairs. Rest space would have been appropriate and the stairs were not wide enough as demonstrated by others (Peacock et al, 2009).

The 102 Minutes Study also shows the extent to which the groups may in fact have been formed by management which was also shown to be the case in Building 4 from the Exploratory Case Study. In this instance the groups were generally larger (10+ persons) so there may be instances for group members to "peel off". If management adopts a procedure where the group is led and followed by wardens then this may not occur. Cohesion would also be a challenge as many of the members would not be immediate colleagues. The roles would also be completely different as the wardens may be seen as the leaders and decision makers.

"Group" or "You and Others" ranked as the second most predominant core consistency in each of the studies (Dwyer and Flynn, 2005 and Parker-Pope, 2008) so that respondents were well aware of the relevance of group formation, behaviour and purpose. The results still need to be viewed further in the context of the individual members, the extent and makeup of the functional limitations and compared with other studies such as Shields et al (2009) and Jiang et al (2012). This comparison will be made following the section dealing with the Focus Group Studies in the next section where movement speeds will be available.

A6.4.5 Discussion of Content Analysis Studies across the Classifications to Amplify Chapter 6

The main discussion of the results from the "102 Minutes" and the "NY Times Blog Studies" will be left until a comparison has been made between the Focus Groups Studies where the same analysis of results will take place using the Ishikawa Chart Model to show the impact of the interacting core consistencies.

The near predominance of the core-consistency in the two studies of the "Group" shows consistency with the Exploratory Case Study. This predominance underpins some of the objectives associated with a primary group (Shields et al, 2009) assisting an individual such as Participant E in the Shields et al Study (2009) in terms of the risk involved. Participant E was a 54 year old female with a BMI of 38 who had severe arthritis of the knee and who did no regular exercise. Participant E lacked stair confidence because of her fear of falling and this most likely would have added to her reduction in speed as well which is equivalent to 0.9 storeys per minute or approximately 0.2m/sec. This would have slowed the group down which appears to have disbanded somewhere else but it does provide a challenge as the other members of the group may not have been strong enough to carry her. Perhaps this was the same scenario as that associated with Comment 102.24 in the "102 Minutes Study". The act of assisting may increase the risk to the group and also impact on the "affiliate group".

The most predominant category within the "You" (Individual) core consistency was Condition which comprised the following:

- Obesity (YC1)

- Fitness (YC2)
- Strength (YC3)
- Co-morbidities affecting stance and gait (YC4)

The “You” or “Individual” core consistency was the most predominant in the NY Times Blog Study where the respondents were individuals and the theme to do with fitness or the lack thereof. The emphasis on Condition within this core consistency provides the “cue” to link the discussion for this section on “You” or the “Individual” with the Focus Group member responses and to examine these in terms of capability or functional ability. Fritz (2009) shows that reduced movement speed is the most reliable predictor of functional ability. Other studies of ageing and loss of strength are also reflected in slower speeds. The ability to walk increased distances (Hulens 2003 and Spearpoint and MacLennan 2012) is also a vital factor and needs to be considered with the travel speed. The Focus Group members either have BMI’s > 30 or are over the age of 45 years so that their functional limitations will provide a better context for discussion.

The “Management” core consistency was the most predominant in the 102 Minutes Study and provides valuable insights into employee/ employer relations especially in terms of the commitment of J.P.Morgan where they viewed their employees as their main asset. They were reminded of the 1993 Bombing experience and held frequent trial evacuations. Groups naturally formed when the wardens decided there was a problem. J...P.Morgan had over 2000 employees and therefore their local management/evacuation procedures could override a lack of initiative or information from the central emergency management organisation. Many of the responses from survivors were critical of management so that the impact of their decisions and strategy on group formation, provision to be made for those with functional limitations and the maintenance of the stair environment are extremely relevant. These issues will also be revisited under the Focus Group section.

The “Stair” core consistency was the least predominant. The main category within this core consistency dealt with the width of the stairs. Shields et al (2009) commented that stairs should be wide enough for navigating by those with functional limitations. Stairs in Towers 1 and 2 were found to be too narrow (Pauls et al, 2007, Averill et al, 2005). This finding was in terms of flow. Shields et al (2009) recommends 1200mm but this would require two handrails for those with functional limitations as commented in the “NY Times Blog” responses. It is interesting to note that Pauls et al (2007) recommend a wider stair of the order of 1500mm. Once again the concern here for those with functional limitations would be reach. Participant E’s body ellipse is not known although it could be calculated from the height and BMI, using data from “CT Scan Imaging” spread sheets from a study by Geraghty and Boone (2003), that would even challenge the 1200mm width. Participant E still required assistance. This would be the case for the person in Comment 102.24 from the 102 Minutes Study (Dwyer and Flynn, 2005). There is a need to resolve this issue.

A6.5 FOCUS GROUPS ANALYSIS

A6.5.1 Overview

There are three Focus Groups included in this section:

- BMI Benchmark Group comprising 10 “young” office workers below the age of 40 years and one 40+ years who undertook a vigorous exercise programme in accordance with the IPAQ (Sjostrom et al, 2005) and were therefore classified as “fit”.

- “Larger Figure” Focus Group comprising office workers with a BMI classification of overweight+(WHO, 2011) and who were conversant with trial evacuations being part of a building set up where the emergency control organisation was actively committed to full scale practices and had a limited functional limitation classification procedure in place that encompassed the model put forward by Matheson (2003).

- “Mature-Age Office Worker Focus Group comprising office workers with an age over 45 years (Kossen and Wilkinson, 2010) from the same building set up as the “Larger Figure” Focus Group.

The “BMI Benchmark” Focus Group comprised observers from the 2008-2010 case studies so that they were immersed in the gathering of data and were conversant with respondent occupant trial evacuation behaviour and stair use. The two other focus groups were selected from workers in the Sydney Building M6 one of the buildings studied in Cycle PDSA 3 of the 2008-2010 Case Study.

The theme that was now available to the author was to investigate the impact of experience on the performance of occupants on stairs. A BMI

Benchmark Focus Group provided a better view of the context when reviewing similar recent studies connected with the WTC 9/11 incident and associated research studies (Galea et al, 2008 and 2008a; Peacock et al, 2009; Jiang et al. 2012; Boyce et al, 2011) when looking at "free" descent speeds as opposed to those masked by extensive delays.

A6.5.2 Results from Focus Groups

BMI Benchmark Focus Group

Christchurch Site and Sub Group

The Christchurch Site comprised a former 20 storey office in the Christchurch CBD which is now being demolished due to the February 2011 earthquake. The type of stair involved is a scissor stair as shown in Figure A32

Each member of the group recorded their descent on a Dictaphone with the appropriate hands free microphone so as not to restrict the movement action cycle. The taped data was downloaded as sound files and interrogated to obtain the necessary information.

Results are presented for:

- Table of individual characteristics gathered from completed questionnaire
- Table of stair descent times and speeds on a storey by storey basis – mean speeds are shown so that they can be compared directly with other studies in the discussion section.
- Regression of no. storeys coped vs. fitness level.

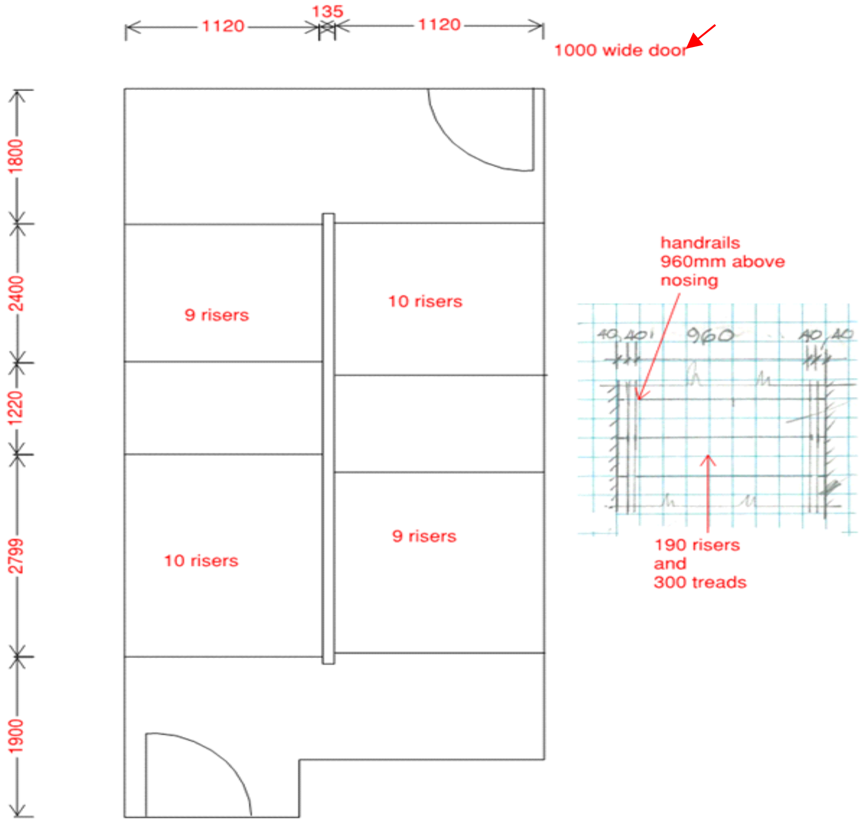


Figure A32: Diagrammatic stairwell plan Christchurch Building

Table A94 below shows some relevant physical individual characteristics for the five Christchurch members of the BMI Benchmark Sub Group. The participants are all male and all below the age of 40 years. Participant number five does not exercise and has reduced vision. Participant number three has a BMI that is classified as obese. This male has a high percentage of “muscle” due to the fact that he plays competitive rugby-league and follows a strict training regime. Participant four has large feet (UK 13). All waist sizes are well under 900mm which is a more meaningful measure than BMI (Serrano-Sanchez et al, 2010) on the basis of adiposity.

SCHEDULE OF PARTICIPANTS' INDIVIDUAL CHARACTERISTICS										
Participant No.	1	1	2	2	3	3	4	4	5	5
Age	33		32		39		26		29	
Gender	m		m		m		m		m	
Height	1830		1800		1651		1980		1760	
Mass	87		70		86		91		80	
BMI	26		21.6		31.6		23.2		25.8	
waist size	864.0		820		864		889		813	
Foot size	8.5		9		8		13		10	
no. storeys cope	**40**	**(IPAQ)2**	**35**	**(IPAQ)2**	**40**	**(IPAQ)2**	**200**	**(IPAQ)3**	**20***	**(IPAQ)1**
*** lower number storeys as this person has problem with the definition of each step after turning through 20 floors - he wears spectacles.**										
(yellow)	Indicates uinclusion of vigorous exercise									
(white)	walking only exercise									

Table A94: Christchurch BMI Benchmark Sub Group - Individual Characteristics *(R^2=0.72, p<.01 – reasonably significant for Y= IPAQ level of exercise and X= no. storeys coped)*

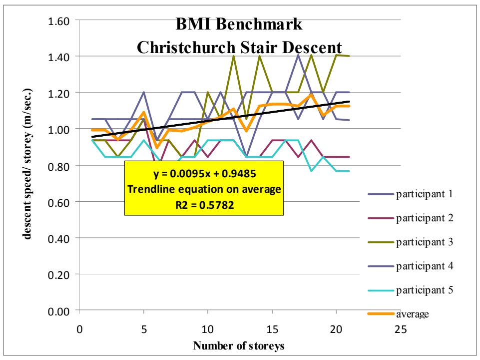
On the basis of the information described above and in Table A95 the following factors are reflected in the descent times and speeds:

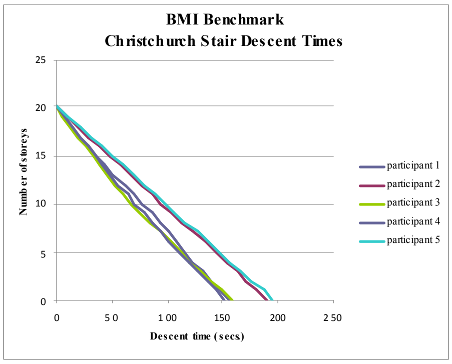
- Knee injury from sport for participant 3. BMI not seen as an issue because waist circumference was less than 900mm.
- Participant 5 did not exercise and had reduced vision.
- Participant 4 had size 13 (UK) feet which prevented him from facing front on when going down the stairs.

BMI BENCHMARK STAIR DESCENT GROUP 1 - CHRISTHURCH												
Distance traversed per storey = 8.423m ; Total distance = 168.5; height per storey = 3.420mm ; total height 64.980mm												
Participant No.	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**Average**	**Average**
Time refs	**Cum. Time**	**Des. Speed**	**Cum. Time**	**Des. Speed**	**Cum. Time**	**Des.Speed**	**Cum. Time**	**Des.Speed**	**Cum. Time**	**Des.Speed**	**Cum time**	**Descent Speed**
Floor	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec	(secs)	m/sec
G	156	1.05	190	0.94	158	0.94	153	1.05	196	0.94	171	0.99
1	148	1.05	181	0.94	149	0.94	145	1.05	187	0.84	162	0.99
2	140	1.05	172	0.94	140	0.84	137	0.94	177	0.84	153	0.94
3	132	1.05	163	0.94	130	0.94	128	1.05	167	0.84	144	0.99
4	124	1.20	154	1.05	121	1.05	120	1.05	157	0.94	135	1.09
5	117	0.94	146	0.77	113	0.94	112	0.94	148	0.84	127	0.89
6	108	1.05	135	0.94	104	0.94	103	1.05	138	0.77	118	0.99
7	100	1.20	124	0.84	95	0.84	95	1.05	127	0.84	108	0.98
8	93	1.20	114	0.94	85	0.84	87	1.05	117	0.84	99	1.01
9	86	1.05	105	0.84	75	1.20	79	1.05	107	0.94	90	1.04
10	78	1.05	95	0.94	68	1.05	71	1.20	98	0.94	82	1.06
11	70	1.05	86	0.94	60	1.40	64	1.05	89	0.94	74	1.11
12	62	0.84	77	0.84	54	1.05	56	1.20	80	0.84	66	0.98
13	52	1.05	67	0.84	46	1.40	49	1.20	70	0.84	57	1.13
14	44	1.20	57	0.94	40	1.20	42	1.20	60	0.84	49	1.14
15	37	1.20	48	0.94	33	1.20	35	1.20	50	0.94	41	1.14
16	30	1.05	39	0.84	26	1.20	28	1.40	41	0.94	33	1.13
17	22	1.20	29	0.94	19	1.40	22	1.20	32	0.77	25	1.19
18	15	1.20	20	0.84	13	1.20	15	1.05	21	0.84	17	1.08
19	8	1.05	10	0.84	6	1.40	7	1.20	11	0.77	8	1.13
20	0	1.05	0	0.84	0	1.40	0	1.20	0	0.77	0	1.12
Average DS		**1.09**		**0.90**		**1.11**		**1.12**		**0.86**		**1.01**
	Cells highlighted thus indicates Participant 3 slowing because of knee injury											

Table A95: BMI Benchmark Focus Group Descent Speeds

The results in Table A95 do not really reflect the limited functional limitations which were mainly restricted to participant 5. He was the slowest with a total descent time of 196 seconds. Participant 5 was cautious over the first few storeys as he became familiar with the stairs and adopted a descent strategy that suited him speeding up to 0.94m/sec from 0.77m/sec and then slowing down due to the onset of fatigue to 0.84m/sec. The variation in descent speed is shown in Figure A33(a). Participant 3 did not show any major signs although the knee injury did slow the descent from level 8 onwards although he made the comment about the pain at level 6.





(a) **(b)**

Figure A33 (a) and (b): BMI Benchmark Christchurch Descent speeds and times

Figure A33 (b) shows two clusters of data in terms of stair descent times where the fastest cluster varies from 153 seconds for participant 4 (foot size did not pose any problems with foot placement due to tread size of 300mm so that the foot overhang would have been less than 25mm) to 158 seconds for participant 3. The latter obviously was prepared to work through the pain for the last 7 storeys.

The trend line on Figure A33(a) shows a general slowing down across all five participants which is consistent with the Sydney Sub Group (speed = .0095x(distance traversed) + 0.9485). This equation accounts for 58% of the variance. The number of storeys in this situation was 21 which will be shown in the 2008-2010 Case Study to be an apparent limiting barrier for many with functional limitations.

Sydney Site and Sub Group

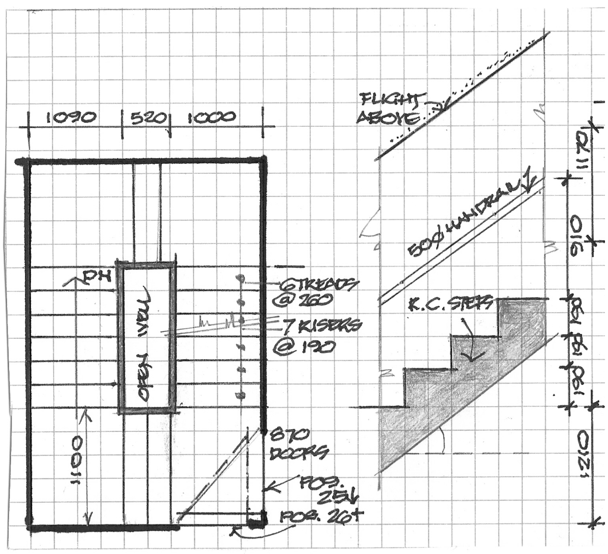


Figure A34: Sydney BMI Benchmark Subgroup

Diagrammatic Plan view - Stair One

CALCULATIONS

Storey height = 19X 190mm = 3.610m

Distance traversed = 9.058m per storey / 244.6m

Total traversed height to level 5 = 97.470m

The Sydney Site comprised building M6 from the 2008-2010 Case Study. There were “rich” distracting views (Templer 1992 and Archea et al, 1979) through the wide “void” between the flights (Figure A34). There are four turns per floor and two extremely short flights where accidents are most likely to happen (Templer 1992).

Each member of the group recorded their descent on a Dictaphone with the appropriate hands free microphone so as not to restrict the movement action cycle. The taped data was downloaded as sound files and interrogated to obtain the necessary information.

Results are presented for:

- Table of individual characteristics gathered from completed questionnaire
- Table of stair descent times and speeds on a storey by storey basis – mean speeds are shown so that they can be compared directly with other studies in the discussion section.
- Regression of no. storeys coped vs. fitness level.

SCHEDULE OF PARTICIPANTS' INDIVIDUAL CHARACTERISTICS										
Participant/Gender	Participant 1 - Male		Participant 2 - Female		Participant 3 - Female		Participant 4 - Male		Participant 5 - Male	
Age	31		35		30		24		24	
Gender	m		f		f		m		m	
Height	1880		1650		1730		1870		1910	
Mass	90		74		62		67		70	
BMI	25.5		27.2		20.7		19.2		19.2	
waist	864.0		800		770		740		740	
Foot size	12		8		5		9		7.5	
No storeys cope	32+	3	32+	1	32+	3	50	1	50	2
(yellow)	Indicates inclusion of vigorous exercise - Participant 3 - this did not include walking									
(white)	walking only exercise									

Table A96: Sydney BMI Benchmark Subgroup – Individual Characteristics ***(R^2=.611 and p<.05- moderately significant for Y=IPAQ level of exercise and X=no. storeys coped)***

Table A96 above shows some relevant physical individual characteristics for the five members of the Sydney BMI Benchmark Sub Group. There are two female and three male participants. All participants are below the age of 40 years. Participant number four does not exercise regularly. Participant number two has a BMI that is classified as overweight and yet undertakes a vigorous exercise regime as designated in the IPAQ short form (Sjostrom, 2005). She does have asthma. Participant one has large feet (UK 12). All waist sizes are well under 900mm for males and 800mm for females which is a more meaningful measure than BMI (Serrano-Sanchez et al, 2010) on the basis of adiposity.

BMI BENCHMARK - STAIR DESCENT- STAIR 1 - GROUP 2 - SYDNEY												
Distance traversed per storey =9.058 m ; Total distance = 244.6m; storey height = 3.610m; total height = 97.47m;												
Participant No.	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**Average**	**Average**
Time refs	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**	**Cum. Time**	**descent speed**
Floor	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)	Time (secs)	(m/sec)
5	199	1.29	359	0.65	242	1.01	328	0.75	295	0.75	285	0.89
6	192	1.29	345	0.65	233	1.13	316	0.82	283	0.75	274	0.93
7	185	1.29	331	0.75	225	1.13	305	0.75	271	0.75	263	0.94
8	178	1.13	319	0.60	217	1.01	293	0.75	259	0.70	253	0.84
9	170	1.13	304	0.65	208	1.01	281	0.70	246	0.82	242	0.86
10	162	1.01	290	0.65	199	1.01	268	0.70	235	0.70	231	0.81
11	153	1.13	276	0.65	190	1.01	255	0.75	222	0.75	219	0.86
12	145	1.29	262	0.65	181	1.01	243	0.70	210	0.75	208	0.88
13	138	1.29	248	0.65	172	0.91	230	0.75	198	0.82	197	0.89
14	131	1.29	234	0.70	162	0.91	218	0.75	187	0.75	186	0.88
15	124	1.13	221	0.60	152	1.01	206	0.70	175	0.91	176	0.87
16	116	1.13	206	0.65	143	1.01	193	0.82	165	0.82	165	0.89
17	108	1.13	192	0.70	134	1.01	182	0.70	154	0.82	154	0.87
18	100	1.29	179	0.65	125	1.01	169	0.82	143	0.82	143	0.92
19	93	1.29	165	0.65	116	1.01	158	0.70	132	0.82	133	0.89
20	86	1.13	151	0.60	107	1.01	145	0.82	121	0.82	122	0.88
21	78	1.29	136	0.65	98	1.01	134	0.70	110	0.82	111	0.89
22	71	1.13	122	0.70	89	1.13	121	0.70	99	0.91	100	0.91
23	63	1.13	109	0.70	81	1.13	108	0.75	89	0.91	90	0.92
24	55	1.29	96	0.70	73	1.01	96	0.75	79	0.82	80	0.91
25	48	1.13	83	0.75	64	1.01	84	0.75	68	1.01	69	0.93
26	40	1.29	71	0.75	55	1.01	72	0.75	59	1.01	59	0.96
27	33	1.29	59	0.70	46	1.01	60	0.75	50	0.82	50	0.91
28	26	1.13	46	0.75	37	1.01	48	0.75	40	1.01	39	0.93
29	18	1.29	34	0.75	28	1.01	36	0.75	31	0.91	29	0.94
30	11	1.51	22	0.91	19	1.01	24	0.75	21	0.82	19	1.00
31	5	1.81	12	0.75	10	0.91	12	0.75	10	0.91	10	1.03
32	0	1.81	0	0.75	0	0.91	0	0.75	0	0.91	0	1.03
Average DS		**1.26**		**0.69**		**1.01**		**0.75**		**0.84**		**0.91**

Table A97: Sydney BMI Benchmark Sub Group Descent Times and Speeds

Table A97 shows the resultant descent times and speeds for the 32 storeys. It is interesting to note here that:

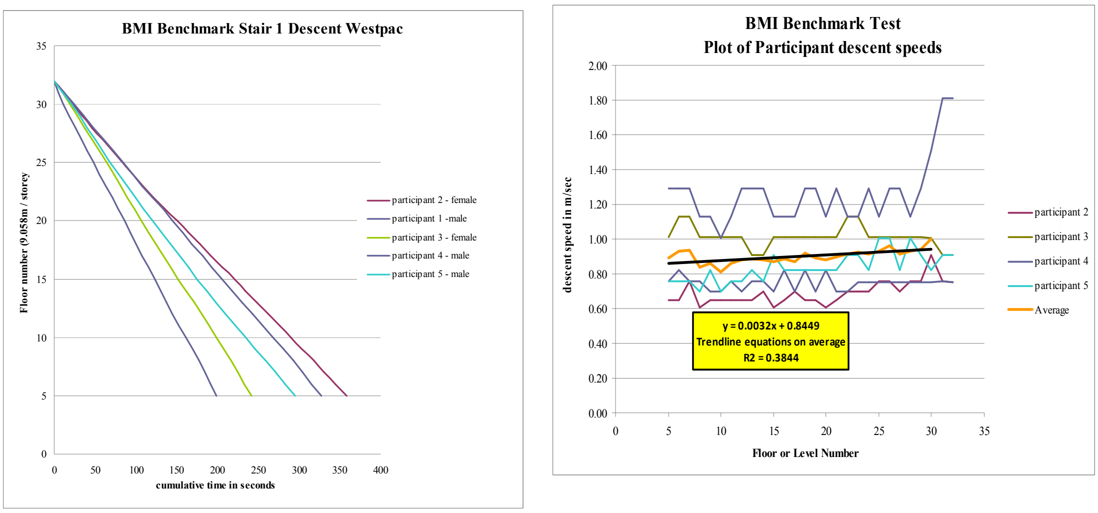
- Participant one undertook a vigorous exercise regime, had a BMI of 25.5 and a waist measurement less than 900mm. His average descent speed was 1.26m/s as compared with the 1.2m/s presented by Shields et al (2009) and Fahy and Proulx (2001).

- Participant two also undertook a vigorous exercise regime but has asthma. She has an 800mm waist measurement but no signs of adipose tissue. Her descent speed was the slowest at an average of 0.69m/s. Her comments on the sound file indicate problems in the vicinity of level 24. She had problems with her footwear.

- Participant three undertook a vigorous exercise regime regularly playing netball. Her waist measurement was less than 800mm. Her descent speed was the second fastest out of the group at an average of 1.01m/s and she overtook participant two.

- Participants four and five, both male, were almost completely identical in physical characteristics and although participant four reported that he did not exercise regularly his descent speed did not decrease with distance whereas participant five seemed to tire from level 16 downwards. No reason was provided for this either on the questionnaire or from his comments on the sound file.

There is a graphical presentation of the above results in Figure A35(a) and (b). The variance in descent speeds may reflect the functional limitation of participant two. The overall trend in descent speeds is a slowing down due to the number of storeys (descent speed = 0.0032 no. storeys + 0.8449). This only accounts for 38.44% of the variance which is only moderately significant ($p<.05$). Once again this corresponds with comments made by Shields et al (2009) in terms of slowing down although their comments are made in the context of those with functional limitations.



(a) (b)

Figure A35 (a) and (b) Sydney BMI Benchmark Sub Group - Descent Times and Speeds

When the combined results from Figure A36 are examined the trend line equation alters slightly to descent speed = 0.0027*no. storeys + 1.057 but it still indicates a small reduction in speed related to distance or height traversed. Overall the benchmark trend is still between 1.00 and 1.2m/sec which is in line with those suggested by others (Shield et al 2009 and Fahy and Proulx, 2001). The results of the survey for both the Sydney and Christchurch BMI Benchmark Sub Groups are presented in the next section, “Combined BMI Benchmark Group Questionnaire Ratings”.

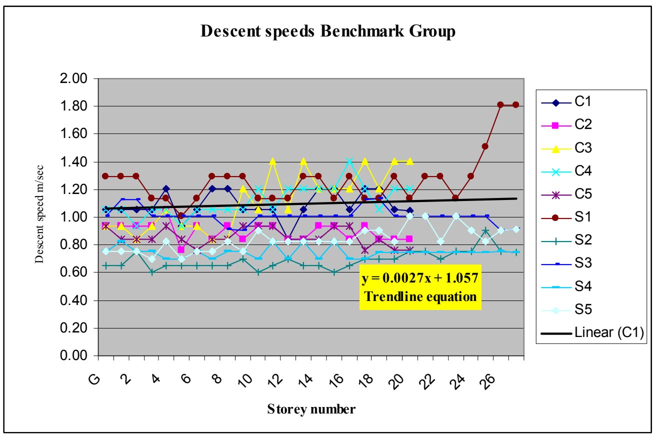


Figure A36: Combined BMI Benchmark Focus Group Descent Speeds and Trends

Combined BMI Benchmark Group Questionnaire Ratings

Table A94 and Table A96 show a summary of the individual characteristics used to comment initially on the descent speeds.

In order to triangulate with the actual stairs used by these two groups the following points should be noted:

- Christchurch Stair:
    - Tread width = 300mm / Riser = 190mm / Pitch = 32.33^0
    - Clear width of stairs = 1000mm
    - No. turns =1
    - Scissor stairs broken by intermediate landing at mid point
    - Handrail height = 980mm and diameter of 40mm with two handrails provided
    - Stair legibility would pass contrast test of 0.3 set down in AS1428.1:2009
    - Stairs were ventilated and illuminated to standard.
- Sydney Stairs:
    - Tread width = 250mm / Riser = 190mm / Pitch = 37.23^0
    - Clear width of stairs = 1000mm
    - No. turns = 4
    - 4 flights per storey with two short flights of three – four risers and two longer flights of seven risers.

- Handrail height = only a single handrail 910mm in height and diameter of 40mm
- Stair legibility would not pass contrast test of 0.3 set down in AS1428.1:2009
- Stairs were ventilated and illuminated to standard.

The Sydney stairs are poor in terms of pitch, width of tread, legibility and availability of suitable handrails. Another possible problem with the Sydney stair already mentioned above is width of the void between the flights in terms of "rich views" (Archea et al, 1979). On the other hand the Christchurch stairs are seen as being reasonably comfortable and legible with two handrails and a minimum number of turns per storeys.

The responses from the BMI Benchmark Group member questionnaires are summarised in Table A98. The following triangulation comments are made:

- Christchurch Stairs
  - Handrails - respondents did not agree handrails were easy to use. No functional limitations. Most stated lack of contrast.
  - Step legibility – all were in agreement.
  - Too steep (32.33^0) – most disagreed so that pitch was acceptable.
  - Treads too narrow – 3 out of 5 participants agreed and this triangulates well with the minimum shoe size of the group which was a UK 9. The other two participants were satisfied and their shoe sizes were less than 9.

- 4 out of the five participants thought that the number of flights were manageable which seems to agree with the 20 storey barrier found in the Exploratory Case Study.

- Sydney Stairs:
    - Handrails – only one set provided and all agreed that it was at the right height and was graspable. This included participant two who used them.
    - Step legibility – 4 out of 5 were in agreement but participant 2 with the asthma did not agree. Lack of contrast in assessment.
    - Too steep (37.33^0) – only participant 2 agreed with this which does not support the scale in the New Zealand Compliance Document D1 (DBH, 2006, p4). AS 1428.1:2009 would partly support participant 2 being the Australian Access Standard.
    - Treads too narrow – 2 out of 5 participants agreed and this triangulates well with the maximum shoe size of the remaining group being UK 9. Participant 2 was concerned with foot placement but it was her footwear that was the issue. Participant 1 had size UK12 shoes but also the fastest descent rate. He still had problems with foot placement.
    - As would have been expected 32 storeys was acceptable except that participant 2 would most likely require places to rest because of the asthma. This is merely an observation.

As far as the BMI Benchmark Group is concerned the critical issue is the width of the treads followed by the pitch of the stairs. This may alter for the Fuller Figure and Mature Age Focus Group which may be found in **Error! Reference source not found.**.

BMI Benchmark Group Members Stair Descent Experience Schedule

Participant / Element	S*1	S*2	S*3	S*4	S*5	C*1	C*2	C*3	C*4	C*5
Health Condition	None	Asthma	None	Poor Vision	None	None	None	Knee cartilage	None	None
Falls	None	None	One	None	One	None	None	None	None	None
Handrail easy	1	2	1	1	2	1	4	1	1	1
Step legibility	2	4	1	1	2	1	2	1	2	1
Too Steep	5	2	5	4	5	4	5	4	5	4
Narrow treads	2	2	4	4	4	4	1	5	2	2
Too many flights	5	5	5	5	5	5	2	4	4	5
Lower limb discomfort	5	5	5	1	4	5	2	2	2	5
Fear of fall	4	5	5	5	5	4	5	4	5	5
Dysponea	5	5	4	5	5	5	5	2	5	5
Chest discomfort	5	5	5	5	5	5	5	5	5	5
Fatigue	5	5	5	4	5	5	5	2	4	5

S = Sydney test; C = Christchurch test; *Scale: 1= strongly agree; 2= mildly agree; 3= neutral; 4= mildly disagree; 5= strongly disagree*

Shading	Comment	Legend and comments
(dark grey)	*Participant S1, male, with size 12 shoes found steps too narrow so that he placed feet at 45^0*	
(light grey)	*Participant S2, female with size 8 shoes found steps too narrow, steep and illegible after while*	
(beige)	*Participant C2, male with size 9 shoes found 300mm treads too small and had sore knees*	
(peach)	*Participants C4, male, size 10 shoes found 300mm treads too small/ calves hurt and C5, male with size 13 shoes found 300mm treads too small.*	

Table A98: BMI Benchmark Focus Group Questionnaire Analysis

In line with the aim for “the number of storeys that participants could cope with” correlated with their IPAQ exercise ratings (Sjostrom et al, 2005) the findings for the BMI Benchmark Sub Groups are:

- Christchurch – R^2=0.72 and p<.01 (reasonably significant) so that exercise rating for this group could predict 72% of the variance of number of storeys.
- Sydney - R^2 = 0.6 and p<.01 (reasonably significant) so that exercise rating for this group could predict 60% of the variance of the number of storeys.

These results are only for small samples. Adjusted R^2 values would be less. The only support may be found in the slowing down in descent speeds as a direct function of the number of storeys (distance traversed) summarised in Figure A36.

Focus Groups with Trial Evacuation Experience and Functional Limitations (Results)

The office building from which the two specialist focus groups were drawn from was Building M6 of the 2008-2010 Case Study. It was not possible to measure descent speeds for the members of these two groups for health and safety reasons. A walking test was of 40m was applied which was converted to represent an average stair descent speed from studies on the relationship between the two (Riener et al, 2002 and Fujiyama and Tyler, 2010).

Fuller Figure Office Workers

The Schedules of "Initial Comments on Core Consistencies" are set out below in Table A99 to Table A102 with relevant notes setting out major differences with outputs from the "Content Analysis Studies" as a note against each table. This applies to all the core consistencies except for "Management". The Ishikawa Chart Prompt was changed for these two focus groups at the request of the Building's Emergency Control Organisation so that the core consistency of "Management" was replaced by "Anything Else". This Group of comments was broken down into the same core consistencies used for the Content Analysis Studies (Dwyer and Flynn, 2005 and Parker-Pope, 2008). The results associated with A99 to Table A102 are presented under the core consistencies.

Table FF 1	*YOU ELEMENT*						
Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (J)	F	Knee	✓				• Knee reconstruction • Often tired • Often stressed
B(W)	M	0	✓				• Nothing to add
C(L)	M	Reduced Vision	✓				• Wrinkled retina – difficulty with depth perception – blurred vision • Difficulty locating steps • Last step in each flight – trips • Lack of step marking causes problems
D(M)	M	Knees/ Height/large feet	✓				• Big feet – difficulty with small steps • Crabs down stairs – relies on handrails for stability • Sore knees but can withstand pain – limit in no. storeys • Lot slower after say 15 storeys
E(?)	M	Not fit Arthritis	✓				• Extremely unfit • Arthritis in knees which compromises no. of storeys that he can evacuate
F(K)	F	Weak ankles	✓				• Heels cause her problems
G((N)	F	Weak ankle Reduced vision Cognitive	✓				• Footwear problems – especially heels • Weak ankles – keeps turning over • Multi focal glasses – difficulty in locating steps • Orientation – needs signage / landmarks
H(G)	M	DOMS in Calves Reduced vision	✓				• Damaged calf muscles downhill running when younger • Heats up quickly – fatigue – not fit • Falls on steps – difficulty locating – fall at main station

Table A99: Fuller Figure Initial Comment Schedule – Core Consistency "You"

Note: Compared with the comments under Content Analysis these comments refer to the individual themselves specifically and therefore will complement the Content Analysis Discussion because of the members' perception of themselves.

Table FF 2	*YOU AND OTHERS*						
Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A(J)	F	Knee		✓			• Being held up by slow movers – increases stress • Crowding creating undue delays as above
B((W)	M	0		✓			• None
C(L)	M	Reduced Vision		✓			• He is slow walker embarrassed at holding others up – stresses him no end – actual fear • Scared holding up fire-fighters • Also slow mover because of vision problem
D(M)	M	Knees/ Height/large feet		✓			• Being held up initially by slow movers • Annoyed by noise and delays due to people talking in groups
E(?)	M	Not fit Arthritis		✓			• Very slow mover – stressed by not being able to keep up with group • Easily fatigued – no. of storeys due to having to keep up with group.
F(K)	F	Weak ankles		✓			• People not focussed on what they are doing and causing confusion within group / others • Could instil panic amongst group in emergency
G(N)	F	Weak ankle Reduced vision Cognitive		✓			• Embarrassed / stressed as she would hold others up – potential for fall with weak ankle
H(G)	M	DOMS in Calves Reduced vision		✓			• Crowding – having people too close so you can't see the stairs – increases risk of falling – others falling. • Also when others do not care about his problems

Table A100: Fuller Figure Initial Comment Schedule – Core Consistency "You and Others" (Group)

Note: Under every comment made against specific individual members there is a theme of self focus as opposed to the Content Analysis Studies. They are to do with being embarrassed as a slow mover and/or falling, tiring because of having to keep up with the group, and having vision of stairs reduced because of the presence of others. The difference is most likely because these occupants feel somewhat vulnerable du to their functional limitations.

Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A(J)	F	Knee			✓		• Needs handrail to feel more confident • Signage to each level for orientation • Marking on steps for legibility
B((W)	M	0			✓		• Not wide enough between handrails • Treads too narrow • Stair design has not changed with body shape and foot size • All elements (steps/ handrails/walls) same grey colour – orientation – need to know level and direction of travel / impact on falls/ • Vital safety elements such as edge of treads and handrails should be highlighted • Must avoid 'whiteout' for reasons of the above and also if smoke penetrates stairwell • Wallpaper effect
C(L)	M	Reduced Vision			✓		• Poor edge delineation of steps – wallpaper effect • Whiteout effect where handrails and steps not marked • Where does each flight stop and start?
D(M)	M	Knees/ Height/large feet			✓		• Stairs too steep and treads too small • No variation in direction – repetitive turning – wallpaper effect compounded – dizziness • Disorientation with no signage / whiteout etc. • Very noisy – echoing from talking in groups – very intimidating will increase further with pressurisation fans and alarms • Temperature – e.g. in Adelaide was 46^0C
E(?)	M	Not fit Arthritis			✓		• No space provided on landings for resting • No space provided for overtaking - stairs
F(K)	F	Weak ankles			✓		• Constant circular flow - no. of turns – dizziness • Two lanes for passing – wider between handrails or resting places say every set number of floors • Larger landings for resting • Whiter out problems with orientation and risk of falling • Needs to know location at any point – signage required – large numbers on walls – nosing markings
G(N)	F	Weak ankle Reduced vision Cognitive			✓		• Narrow treads • Downwards spiral – problems with orientation and falling because of wallpaper effect • Whiteout exacerbates downward spiral
H(G)	M	DOMS in Calves Reduced vision			✓		• Too steep • Treads too small for feet • Increases fear of falling (steep and small treads) • Downwards spiral with whiteout disorientates and increases risk of falling – falls history on stairs – related falling incident at main Sydney Station. • Concerned with door encroachment

Table A101: Fuller Figure Initial Comment Schedule – Core Consistency "Stairs"

Note: This Schedule should be read carefully in association with Table (xx) where these concerns were rated by the respondents in the questionnaires they answered. This table allows for some initial triangulation between actual elements and functional limitations

Table FF 4		ANYTHING ELSE					
Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A(J)	F	Knee				✓	• Crowding not going anywhere
B((W)	M	0				✓	• Nothing to add
C(L)	M	Reduced Vision				✓	• Body odour etc. and lack of ventilation etc.
D(M)	M	Knees/ Height/large feet				✓	• Time taken to get back into building when a trial • Trying to get in touch with loved ones in a real emergency on mobile phone when no reception – increased stress
E(?)	M	Not fit Arthritis				✓	• Are other systems available such as elevators?
F(K)	F	Weak ankles				✓	• Good procedures to stop excessive queuing – phased or sequential evacuation so that floors cleared in sequence and numbers within stairs kept to a minimum.
G(N)	F	Weak ankle Reduced vision Cognitive				✓	• See Stairs for overtaking lane suggestion
H(G)	M	DOMS in Calves Reduced vision				✓	• No additional comments

Table A102: Fuller Figure Initial Comments Schedule for "Anything Else"
Note: Comments in this table have been abstracted to the Ishikawa Chart Summary in ***Error! Reference source not found.****.*

Mature Age Office Workers

The Schedules of "Initial Comments on Core Consistencies" are set out below in Table A105 to Table A108 with relevant notes setting out major differences with outputs from the "Content Analysis Studies" as a note against each table. This applies to all the core consistencies except for "Management". The Ishikawa Chart Prompt was changed for these two focus groups at the request of the Building's Emergency Control Organisation so that the core consistency of "Management" was replaced by "Anything Else". This Group of comments was broken down into the same core consistencies used for the Content Analysis Studies (Dwyer and Flynn, 2005 and Parker-Pope, 2008). The results associated with Table A105 to Table A108 will be presented under the core consistencies.

Table MOW 1 YOU ELEMENT							
Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (P)	M	Sore Knees Vision	✓				• Sore knees that would cause problems with > 32 storeys
B(Male 1)	M	None stated	✓				• Very slow walker- scared / stressor- he will hold others up. • Reliant on handrail
C(Woman1)	F	Vertigo Sore right knee (arthritis)	✓				• Hates to be held up as her knee seizes up • Walking behind people in loose footwear e.g. 'flip-flops' or thongs as she is scared of stepping on them • Wearing loose shoes herself scared of falling • Falling due to vertigo e.g. large stairwell opening.
D(Woman2)	F	Falling history Vestibular problem	✓				• Has a vestibular condition (not elaborated) so that she has an inordinate fear of falling • Always holds on to handrail
E(Male 2)	M	Damaged calf muscles	✓				• Legs very sore so that no of storeys that he can cope with will be affected • Very unfit due to lifestyle and condition (15 floors). • Needs to practice
F(Male 3)	M	Poor Vision Damaged Leg	✓				• Poor vision even with glasses • Soreness in leg • Constant turning causes problems
G(Male 4)		Poor Vision	✓				• Poor vision- multi focals with tinted lenses that cause problems with depth perception and locating of steps

Table A105: Mature Age Initial Comment Schedule – Core Consistency "You"
Note: Compared with the comments under Content Analysis these comments refer to the individual themselves specifically and therefore will complement the Content Analysis Discussion because of the members' perception of themselves

s.

Table MOW 2	*YOU & OTHERS ELEMENT*						
Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (P)	M	Sore Knees Vision		✓			• Marked fear of crowds in terms of others falling and causing him to fall as well of pressure being required to help • Seeing steps blocked by others.
B(Male 1)	M	None stated		✓			• Scared of holding others up and impact of fast descent on his ability • Queuing delays • Potential of crowds for panic/ confusion
C(Woman1)	F	Vertigo Sore right knee (arthritis)		✓			• Hates to be held up – knee seizes • Others with flip flops or thongs – footwear – increased risk of falling and also one must be careful not to step on loose heel.- falling
D(Woman2)	F	Falling history Vestibular problem		✓			• No relevant comments re this element
E(Male 2)	M	Damaged calf muscles		✓			• No relevant comments re this element
F(Male 3)	M	Poor Vision Damaged leg		✓			• Noise in the stairs due to incessant chatting between members of groups
G(Male 4)		Poor Vision		✓			• Crowds reduce reflectance of surface and clarity of steps making location of steps difficult – caused him to treat as a hazard

Table A106: Mature Age Initial Comment Schedule – Core Consistency "You and Others" (Group)

Note: Under every comment made against specific individual members there is a theme of self focus as opposed to the Content Analysis Studies. They are to do with being embarrassed as a slow mover and/or falling, tiring because of having to keep up with the group, and having vision of stairs reduced because of the presence of others. The difference is most likely because these occupants feel somewhat vulnerable du to their functional limitations.

Table MOW 3	*STAIRS*						
Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (P)	M	Sore Knees Vision			✓		• Treads too narrow – others falling • Amount of turns with monotonous/ whiteout environment • Need two handrails and wider stairs • Highlight nosings and handrails to reduce wallpaper effect • Lack of ventilation and temperature • Organise procedures so that internal accessible third stair can be used • Large numbers on walls for orientation especially when fire doors are missing as these act as landmarks for each level
B(Male 1)	M	None stated			✓		• Tight number of turns so that need to use handrail for stability to overcome dizzy feeling • Temperature in stairs and lack of ventilation
C(Woman1)	F	Vertigo Sore right knee (arthritis)			✓		• No relevant comments re this element
D(Woman2)	F	Falling history Vestibular problem			✓		• Reduced lighting – difficulty finding steps – really serious fear of falling • Holds handrail to counteract fear of falling
E(Male 2)	M	Damaged calf muscles			✓		• 15 floors can be problem
F(Male 3)	M	Poor Vision Damaged leg			✓		• Constant turning is annoying and affects leg • Noise in stairs due to others in stairs • Trials do not reflect emergencies
G(Male 4)		Poor Vision			✓		• Lack of lighting affects especially with tinted glasses so also uses handrail for stability

Table A107: Mature Age Initial Comment Schedule – Core Consistency "Stairs"

Note: This Schedule should be read carefully in association with Table (xx) where these concerns were rated by the respondents in the questionnaires they answered. This table allows for some initial triangulation between actual elements and functional limitations

Table MOW 4 ANYTHING ELSE							
Participant		Condition	Element				Comment
No.	**Gender**	**(Coded)**	**YOU**	**You/ Others**	**Stairs**	**Any/ else**	
A (P)	M	Sore Knees Vision				✓	• Change procedures so that accessible stairs can be used – fire stairs should have accessible standards
B(Male 1)	M	None stated				✓	• There is a potential for panic
C(Woman1)	F	Vertigo Sore right knee (arthritis)				✓	• Procedures on footwear in stairs
D(Woman2)	F	Falling history Vestibular problem				✓	• Lighting maintenance must be high
E(Male 2)	M	Damaged calf muscles				✓	• Procedures for those with conditions that will increase falls potential • Must practice more •
F(Male 3)	M	Poor Vision Damaged leg				✓	• Trial needs to reflect emergency conditions more
G(Male 4)		Poor Vision				✓	• Lighting must be highly maintained - critical

Table A108: Mature Age Initial Comments Schedule for "Anything Else"
Note: Comments in this table have been abstracted to the Ishikawa Chart in ***Error! Reference source not found.***

A6.6 FURTHER DISCUSSION OF EXEMPLAR BUILDING RESULTS FROM APPENDIX A5 IN THE CONTEXT OF PHD STUDY AIMS AND OBJECTIVES

A6.6.1 Generally

The Exploratory Case Study results presented in section A5 covered a total of eight buildings. Two exemplar buildings were selected from the eight as being representative and also as being suitable for further comparison with the six buildings (M1-M6) in the 2008-2010 Case Study. The exemplar buildings are Buildings 3 and 7. Building 3 is similar in terms of height to Building M6 (30 storeys +) and Building 7 is similar to Building M3 (19/20 storeys).

Building 3 and Building 7 stairwell visual images and notes are shown in Figure A37 and Figure **A38** for ease of reference. They are also included in Chapter 4 as well as in Appendix A5.

The purpose of this section is to reanalyse the Exemplar Buildings in terms of the Core Constituencies, triangulate representative category results from the original 1980 Survey Output (SPSS V2.1) and then compare the findings with the PhD Study research questions, aim and objectives.

A6.6.2 Physical Assessment Details for Triangulation

Exemplar Building 3 is 33 storeys in height with the travel distance per storey being 8480mm. Exemplar Building 7 is 20 storeys in height with the distance per storey being 8900mm. The stairs in each building are of reinforced concrete with a steel trowel finish with a PTV of 36+ being a generic value for that type of finish.

Figure A37: Down-flight view of Exemplar Building 3 Stair.

- ***Risers not uniform (10mm)***
- ***Treads 250mm/Risers 190mm Slope=37.5⁰***
- ***Single handrail (75X20mm)***
- ***Clear width = 1000mm approx***
- ***Red signage – floor level no.***
- ***No contrast on surfaces, handrail neutral and not improved by illumination***

Figure A38: Entry door and main landing of Building 7 Stair

- ***Treads and risers relatively uniform***
- ***Treads 250mm/ Risers 190mm Slope=37.5⁰***
- ***Clear width = 1000mm approx***
- ***Single handrail with 30X30mm section but grasp broken by posts***
- ***Floor levels noted on doors (white on black) which are recessed but resting spot not available as the space is within the entry path***
- ***No contrast on surfaces and between steps; illumination poor as shadows cast on steps; Handrail does contrast; stairs well maintained and clean.***

Figure A37 and Figure A38 show typical visual images of the stairwells in each building for ease of reference. A summary of the physical attributes of each stairwell are also included and are self explanatory. These will form the basis for triangulation with the selected results from the 1980 for the categories in the Core Consistencies of YOU (Individual), YOU & OTHERS (Group) and STAIRS. Two categories listed under STAIRS also belong to the MANAGEMENT Core Consistency. The details and comments are shown in Table A113 and will be discussed further in the next section in the context of the summary of the Exploratory Case Study.

The following Observation notes recorded at the time of each of the trial evacuations are recorded below as they also form part of the triangulation issues. These observations apply mainly to the Group and Management Core Consistencies:

- Each of the trial evacuations ended up as uncontrolled evacuations (Pauls 1977) where everyone evacuated when they were ready. This was intended in Building 3 as the Chief Warden left the detailed procedures for each floor in the hands of the fire wardens. This was not the case with Building 7 where a sequential strategy was in place. On the day of the trial evacuation the sound levels for the emergency communication speakers were far too low so that the messages were inaudible. Floor wardens took control and evacuated as quickly as they could.

- The level of Maintenance was adequate except for the illumination in Building 7 where there were shadows cast across some of the flights making them illegible in terms of foot placement. Building 3 was satisfactory in this regard. Both building stairwells were clean and free of obstructions.

- Building 7 group formation appeared to be in the hands of the wardens as the floor wardens “directed” procedures. Occupants in Building 3 appeared to more conversant with what they had to do so that they most likely formed their own groups with work colleagues they knew on the floor.

The total evacuation time for Building 3 was less than that of Building 7 even although the population was some 40% greater for Building 3.

Core Consistency	Category	Question	BUILDING THREE					BUILDING SEVEN					
			s.agree	agree	neutral	disagree	s.disagree	s.agree	agree	neutral	disagree	s.disagree	COMMENTS (
STAIRS	Steepness	**The stair was too steep**	0.7	6.7	25.3	54.7	12.7	0	5.3	22.1	60	12.6	37.5 degrees in pitch only concerns 6% avarged between buildings
	Slip Resistance	Stairs were too slippery	0.7	1.3	15.3	64.7	18	0	3.2	13.7	64.2	18.9	Steel trowel finsih has PTV of 36+ and appears acceptable
	Handrail Grasp	Handrail was awkward to use	7	10.7	22.1	51.7	14.8	1.1	9.5	17.9	53.7	17.9	Equivalent of 30% had problems - agrees with shape of rail.
	Handrail Use	You used the handrail going down the stair	4.1	16.3	19	17.7	42.9	6.5	17.2	20.4	21.5	34.4	Approx 20% used handrail
(INCL. MANAGEMENT)	Lighting adequacy	Lighting was inadequate	0.7	1.3	10.7	66.4	20.8	2.1	3.2	14.9	60.6	19.1	2-5% agreed - Building 3 OK but 7 had shadows - perceived as no issue
(INCL. MANAGEMENT)	Maintenance - cleanliness	Stair was poorly maintained	2	13.3	32	38.7	14	4.3	9.8	32.6	41.3	12	Both stairs were clear and OK - visual agreement
	Stair width	Stairs were not wide enough - felt hemmed i	2.7	17	17	46.9	16.3	1.1	23.2	18.9	42.1	14.7	20-25% thought it was an issue. 1m too small (Pauls et al, 2007) no rest space
YOU (INDIVIDUAL)	Fear of crowds/ density	Stair was uncomfortably crowded	2	13.3	22.7	48	14	1.1	15.8	20	51.6	11.6	16% thought was crowded which reflects fear (see Focus Group) Bldg 7 was crowded.
		Movement too fast - slow movers	0	2	22.1	58.4	17.4	0	1.1	13.8	67	18.1	Speed OK most likley due to group impact - slope would deter fast descent
GROUP			**ex.degree**	**very much**	**moderate**	**slight**	**not at all**	**ex.degree**	**very much**	**moderate**	**slight**	**not at all**	
	Merging - delay -entry defers	Delay people from above passing	**0.7**	**4**	**10.7**	**28.7**	**56**	**3.2**	**5.3**	**9.6**	**27.7**	**54.3**	Both used uncontrolled evac so that 44-46% did experience delay due to merging
	Slow mover problem	Delay because people in front walking too sl	**1.3**	**6.6**	**16.1**	**38.3**	**38.3**	**3.2**	**9.5**	**18.9**	**27.4**	**41.1**	Slow movers were observed - only diarised notes no measurements
	Location of Group formation	Entry on Floor	**8.9**	**21.8**	**21.8**	**21.8**	**26.5**	**1.1**	**12.6**	**20**	**20**	**46.3**	74% in building 3 where evac procedures decentralised; 54% where centralised
	Affiliate Group formation*	In stair	**9.5**	**39.5**	**29.3**	**10.9**	**10.9**	**5.3**	**31.6**	**30.5**	**14.7**	**17.9**	Strong primary group 37-44% abnd those still known but less intimate - ave 38% *
YOU (INDIVIDUAL)	Narrow Treads	Apprehension about safe footing	**0.7**	**4.8**	**6.2**	**20.5**	**67.8**	**1**	**3.1**	**5.2**	**18.8**	**71.9**	Approximately 30% were apprehensive - significant concern about 250 tread
	Steepness / Confidence	Apprehension about personal safety	**0.7**	**1.4**	**3.4**	**19.6**	**75**	**0**	**4.2**	**7.3**	**22.9**	**65.6**	25-34% concerned - lines up with Age profile (45+) and stair slope of 37 degrees
	Knees -arthritis	Weakness in your knees	**2**	**3.4**	**4.8**	**23.8**	**66**	**0**	**3.1**	**0**	**10.4**	**86.5**	Distance confirmed 3=30+ storeys and 7= 20 storeys
	Cardiovascular	Discomfort in chest	**0**	**0**	**1.4**	**6.8**	**91.8**	**1**	**0**	**1**	**2.1**	**95.8**	Small difference but most likley due to distance if any
	Fatigue generally	You were tired or suffering from fatigue	**0**	**0**	**2.7**	**16.2**	**81.1**	**1**	**1**	**1**	**3.1**	**93.8**	Difference of 12% which is due to distance
	Vestibular	Dizziness or balance problems	**0**	**0**	**2.7**	**16.2**	**81.1**	**1**	**1**	**1**	**3.1**	**93.8**	As above - statistics identical

Table A113: Triangulation of Survey Data from Exemplar Buildings 3 and 7 from Exploratory Case Study

Table A114: Fatigue vs. No. Storeys Coped – Regression

(R^2=.76 exponential model - equation is $y=1.9598e^{0.5059x}$ and $p<.01$)

Buildings Numbers			**Building 3 (%age shown)**		**Buildings 2 and 4 (%age shown)**	
Rating scale particulars			**Storey Rating**	**Fatigue Rating**	**Storey Rating**	**Fatigue Rating**
Fatigue rating	**No storeys coped**	**Rating no.**				
extreme degree	<5	1	3.3	0	0	5
very much	>5 to <9	2	6	0	1.1	5.8
moderate	>9 to 14	3	6	2.7	3.8	7.2
slight	>14 to 19	4	3	16.2	22	6.1
not at all	> 20 storeys	5	81.7	81.1	73.1	24.1

Regression details: R^2 = 0.9522 for Building 3 and 0.6541 for Buildings 2 and 4. ($p<0.05$)

Forerunner to later IPAQ survey measuring level of activity in METS per week.

APPENDIX A7: 2008-2010 CASE STUDY RESULTS

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Note: The section numbers in the Appendix A7 follow those in Chapter 7

A7.5 AUTHOR BASED CASE STUDIES

A7.5.1 Assisted Evacuation Case Study

Generally

The following case study is where the author, as an expert immersed in the PhD Case Study, challenged the findings of Adam and Galea (2011) and Zmud (2007) and carried out his own site test where the mass of the individual requiring assistance was some 200Kg.

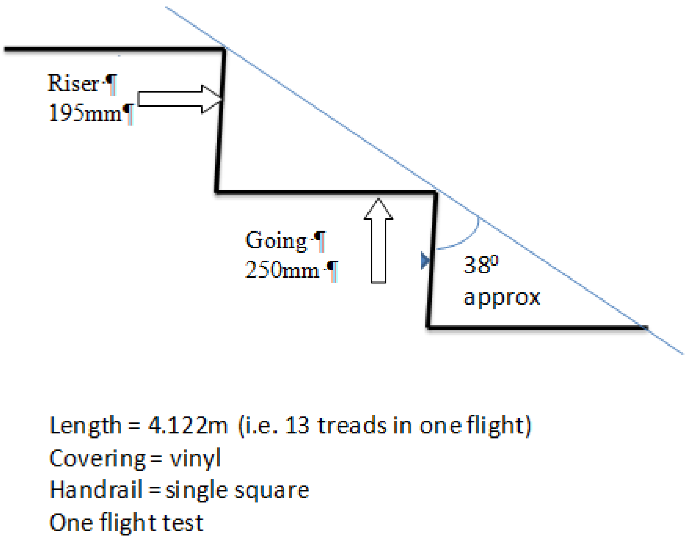


Figure A39: Section through stair showing average stair geometry and pitch

The test stair selected was one that represented a typical high rise building stair such as those found in 2008-2010 Case Study Buildings, Numbers M1 and M3. The Adams and Galea Study (2010) comprised a multi storey ascent so that this will be allowed for in the discussion in the subsequent sections.

The stair geometry is shown in Figure A39 where the pitch is approximately 38^0. This pitch resembles a steep stair so that the test addresses many of buildings constructed in accordance with the minimum going dimensions and maximum riser dimensions in Table D2.13 of the Building Code of Australia (1996 – 2011). It is therefore considered to be a conservative pitch in terms of the performance of the Evac-chair® vehicle, especially the model 1-440.

Figure A40 shows a typical front view of the test stair flight. The nosing contrasted with the dark vinyl floor covering and the black handrails with the light coloured walls. There were a total of thirteen risers.

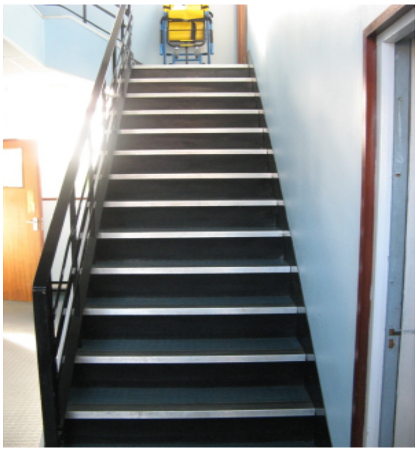


Figure A40: - View of test stair flight

Figure A41 and Figure A42 show the author during tests 4 and 6. Note that the author is below the limit recommended for a single operator but in such instances the operator would be expected to have been properly trained and to participate in this capacity during each trial evacuation.

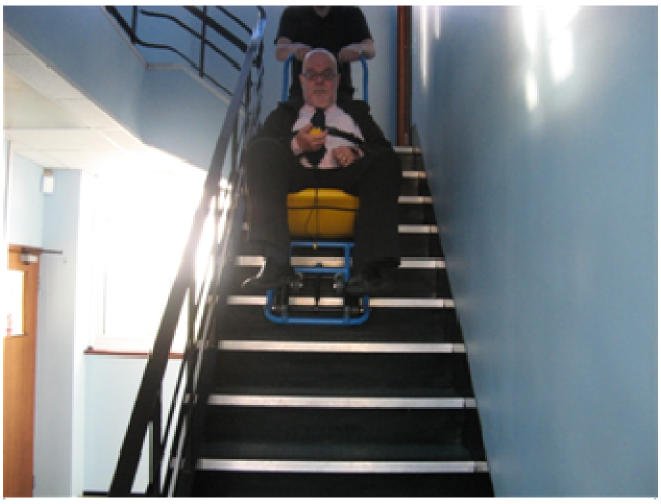


Figure A41: - Test Run No. 4 (single operator)

Figure A42 - Test 6 with 2 operators

Test Procedure and Results

Adams and Galea (2010) utilised a 75kg subject for the Evac-chair test. The likely BMI would have been 22. The author being the person immersed in the PhD case study is still classified as Class III obese having a BMI of 33. During the 1980's he had a BMI of 56. In order to view the descent speed results from the Adams and Galea (2010) study in context the author conducted a test with the permission of the suppliers of Evac-chair using the model 1-440 as the descent vehicle. This model is designed to carry people with a mass limit of 200Kg or 440 lbs.

A total of six test runs were conducted for the reason of internal validity so that the comparison with the Adams and Galea (2010) study could be placed in context. The procedure and results are discussed in Table A119 below.

Characteristics of Respondent					Time and Speed(Comparison with Adams and Galea, 2011)		
Run No.	Mass	BMI	Walking	Evac+Chair®	Time	Speed	A/G Adjusted speed
1	75	22			4.96	0.83	NA
2	130	33			10.22	0.41	NA
3	75	22			8.5	0.49	0.78
4	130	33			11.9	0.35	0.56
5	130	33			12.5	0.33	0.53
6	130	33			12.9	0.32	0.51

Table A119: Test Results and Comparisons

The highlighted column shows the measured speeds adjusted to match Adams and Galea (2010) taking into account speed gained by multiple descent which is similar to speeding up of descent recorded by Peacock et al (2009) for most likely the same factor.

Table A119 shows the respondent characteristics and test type together with the resultant descent time for the flight together with the mean descent speed. The measurement commenced at 'toe-off' the first riser for walking and commencement of movement of the evac+chair® with the key point being the leading knee of the respondent to 'heel-down' on the next lower landing. The travel distance was calculated at 4.122m.

Device	Average travel Time (seconds)	Number of Handlers in Emergency	Average Speed in metres/ second.
1. Evac+ Chair (75kg)	209	1	0.81
2. Carry chair (75kg)	297	3 male or 4 female	0.57
3. Stretcher (75kg)	305	4	0.55
4. Drag mattress (75kg)	272	2	0.62
Drag mattress (180kg)	210	5	0.13

Table A120: Adams and Galea Study (2010)

The travel speeds from the spot test were then adjusted by the ratio of the travel speeds recorded in the study (Adams and Galea, 2010) to that recorded in the test. The ratio was 1.61. This was repeated for tests 4-6 so that the speeds could be compared with the other handling methods in Table A120. It is interesting to note that the 1-440 chair matches that of the stretcher. The highlighted row in Table A120 which represents a mattress drag conducted with the author as a respondent in a New Zealand test evacuation of a large hospital through 4 storeys only resulted in descent speed of 0.13m/sec which is well below the speeds actually measured in the Author's comparative test. A model 1-440 chair would still be within the range of descent speeds recorded in many trial evacuation studies for ordinary stair walking (Fahy and Proulx, 2001).

A7.5.2 Christchurch Earthquake Study – Recount of survivor's stair descent.

Generally

The event as described in Chapter 5.3 concerned the evacuation of an 8 storey office building within 1Km of the centre of the Christchurch CBD. The magnitude of the earthquake was 6.3 with rapid ground surface acceleration. Shaking commenced at 12.51.42pm. The occupants of the sixth level began to evacuate approximately at 12.52.37pm. It is estimated from interviews conducted with the fire warden that the first person from that level took some 30 seconds to exit the building. The opening stair descent speed was approximately 1.2m/sec which compares with the BMI Benchmark Focus Group (0.6m/sec). Both of the individuals concerned wore high heels and had similar intrinsic characteristics.

The author as part of a group formed at the work location entered the stairs at approximately 12.54pm. He took some 80 seconds to exit the building. In so doing he held up the rest of the group and would have fallen if there had not been two handrails provided.

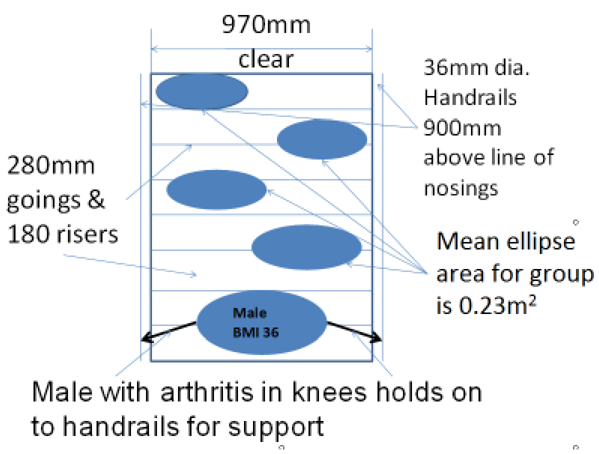
Figure A43: Part view of the exit stair

The stair was constructed of "L" shaped precast concrete sections supported on a steel framework. The latter was damaged during the quake. Water from the domestic water supply "poured" down the entire well so that surfaces were slippery. Lighting remained intact and the evacuation alarms sounded for the entire duration of the evacuation.

Analysis and Discussion

The construction of the stairs and the resultant shaft environment are described in Chapter 5.3. A diagrammatic plan of the author's descending group is shown in Figure A44 below:

Figure A44: Diagrammatic Plan View of Evacuating Group



The average area of the body ellipse projected by the members of the group was $0.23m^2$ and the author's ellipse measured at $0.35m^2$.

The author's intrinsic characteristics included a marked fear of falling, arthritis in each knee resulting from earlier motorcycle accidents and being morbidly obese (BMI = 36). His waist circumference is 1250mm. The stair was equipped with two handrails which the author used to support himself and cope with the pain in his knees. He held up the group behind as shown in Figure A44. A gap opened up between the author and the members of the group ahead. If the author had fallen there is no doubt that others would have helped. The estimated descent speed was 0.6m/sec (free travel) and he considered this to be uncomfortable.

Pauls et al (2007) and Peacock et al (2009) maintain that stairs should be made wider. If the stairs had been 1400mm between handrails, the author would still have been able to reach them and would still have held up the others. The addition of the handrail is what decreased the risk of falling and requiring a number of others to assist as per A7.5.1. If an evacuation chair had been available the descent speed would have been 0.8m/sec with the stress to the rest of the group being offset. The evacuation training did not cater for the author as he had not self designated his characteristics and needs.

The above was presented as a case study at the International Conference on Stair Use Safety held in Toronto in June 2011 in the panel discussion on crowds and stairs (MacLennan and Ormerod, 2011) and is summarised below in Figure A45.

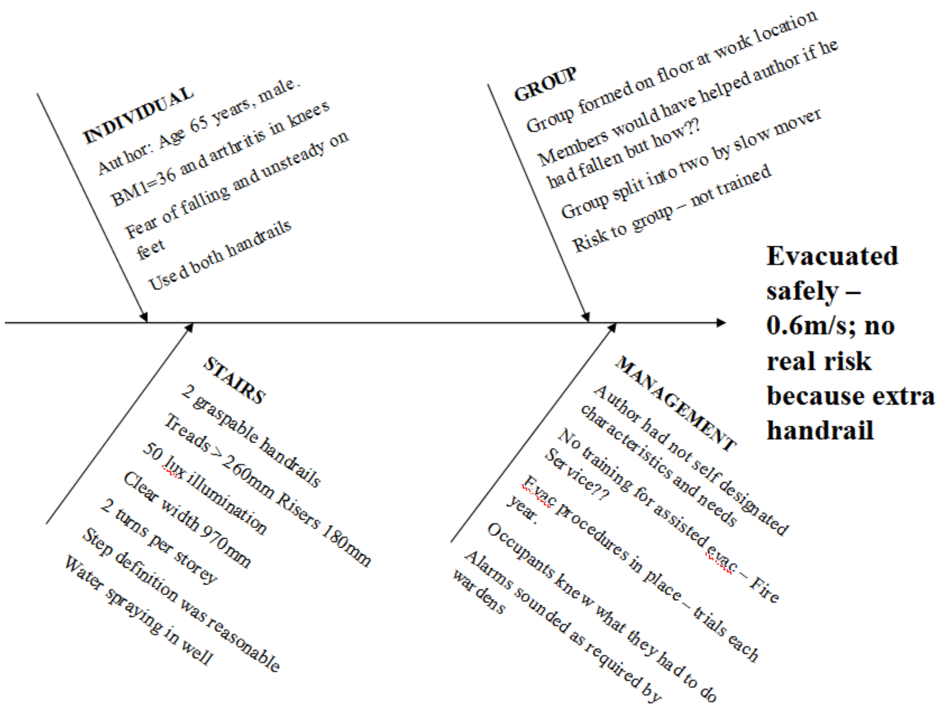


Figure A45: Ishikawa Chart Summary of Author's Earthquake Evacuation Case Study

It should be noted that the building in question was severely damaged and has now been demolished.

Concluding Remarks

The main scenario in this study was to prevent the fall due to lack of support. An extra handrail was provided, the distance to ground level was short (within the range the author could cope with), the members in the group were known and there were evacuation procedures in place. The slope of the stairs was some 34^0 but the author was still outside his comfort zone because of the descent velocity. If the distance had been any greater then he most likely would have fallen as he did in the M2 evacuation. Rest spots were not available.

A7.6 TRIANGULATION

Note: This section includes some information from the Chapter. This is intentional so allow for easy reference to the marked up stair descent charts and schedules. Comments are then available in real time in terms of each trial evacuation.

A7.6.1 Generally

The data to be used for triangulation is introduced as follows:***Interpretation from Video Observations***

Buildings M1 – M6 are each presented separately. The main results are known as "stair descent charts" and are prepared for each stair in each building. These charts show the path of each "observed person" commencing on the landing in the stairwell at the floor they were located on at the time the alarm sounded. The path for each individual or occupant is then shown from that level descending through each floor (Y-axis) until they reach the point of exit measurement which is not necessarily outside the building. This path provides the distance plot against a cumulative time scale shown on the X-axis. Stair descent charts may in certain instances comprise key charts which summarise the evacuation supplemented by other charts that fill in the details.

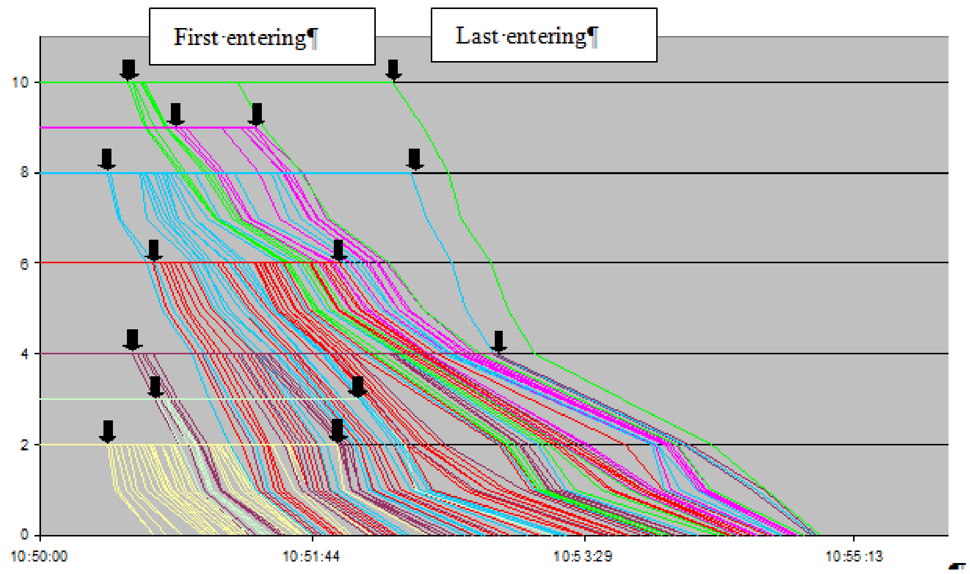


Figure A46: Example of Stair Descent Chart

An example of the stair descent chart for Building M1 is shown in Figure A46.

Density and Velocity

Density and velocity data have been derived from the "stair descent" data for M1-M6 for each stair and are presented as follows:

- Density chart showing variation in density over time at lower measuring point.
- Plot of density vs. velocity with calculated R^2.
- Plot of final level velocity and density over time.
- Data spread sheets for the above plots and charts are not presented and are available in electronic format on a DVD inserted at the end of Appendix A7.

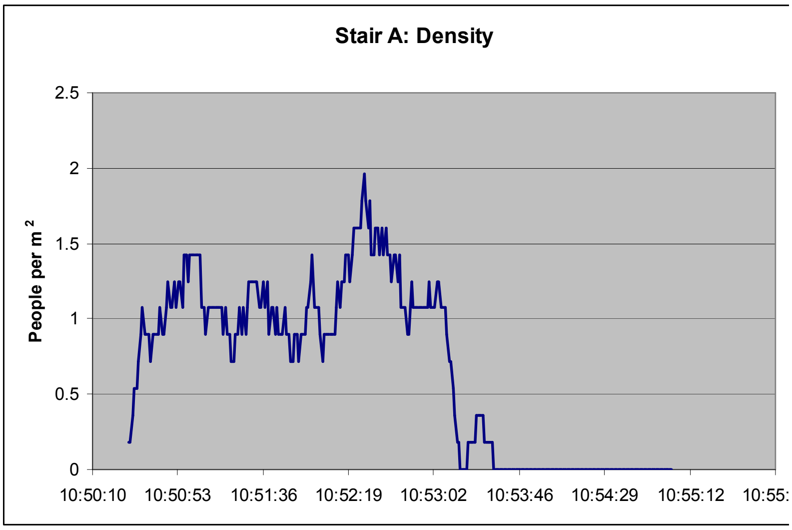


Figure A47: Specimen Plot of Density over Time

Figure A47 shows density over time. Figure A72 shows that density varies between 1-2 persons/m^2 over the duration of the evacuation.

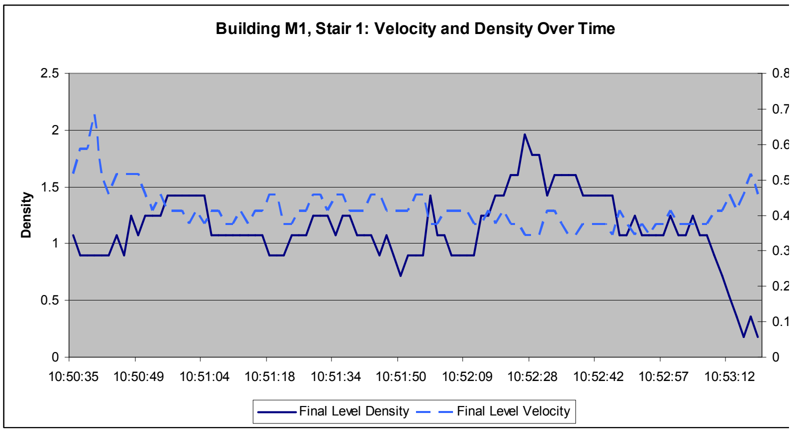


Figure A48: Velocity and Density over Time

Figure A48 compares variations in velocity with changes in density over the period of the trial evacuation. Visually it could be argued that there is only a weak relationship seeing velocity varies between 0.3 and 0.5m/sec over the entire period even when density peaks at 2p/m^2.

Figure A49 shows a scatterplot of density vs. velocity together with a regression analysis. There is a weak relationship which shows that density accounts for 20.54% of the variation in velocity (p<.05 – moderately significant).

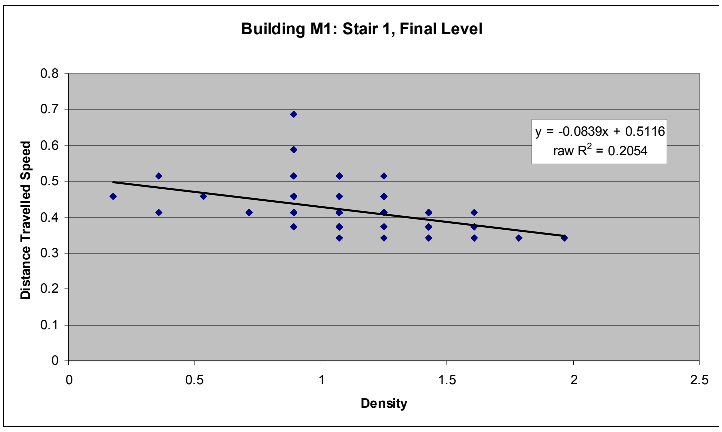


Figure A49: Velocity vs. Density at final level

Observers and Observations

Observers are plotted on the stair descent charts as well. The benefit of this is that group formation can be confirmed and fatigue observed by increase in handrail use as the distance descended increases.

When the descent charts had been constructed from the "video analysts" the descent charts were revisited together with the data and video images to record additional factors such as occupant performance.

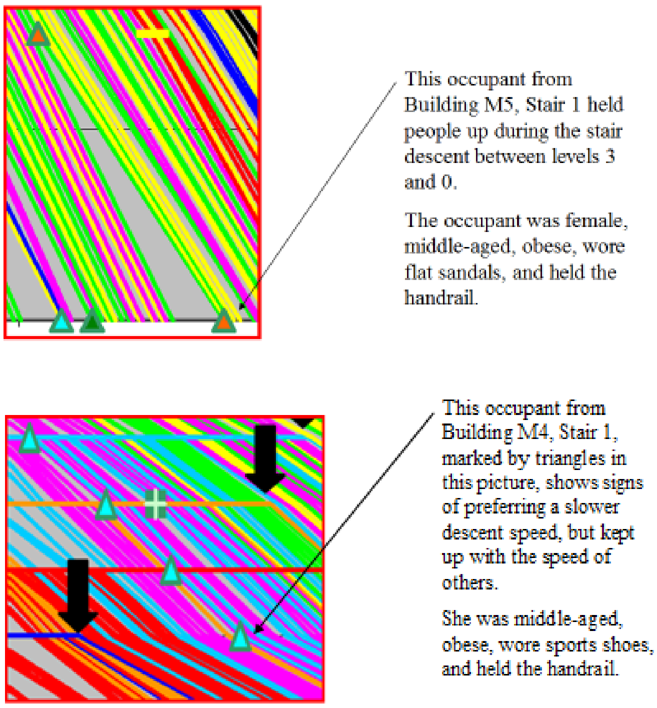


Figure A50: Examples of Symbols added to Descent Charts

Legend for Interpreting Symbols on Graphs

The symbols below are in the form of a Legend for all buildings M1-M6.

Occupants

There are symbols on the stair descent graphs to help with the interpretation of the data. Occupants who looked like they struggled on the stairs, or were overtaken, or held people up are coded by the characteristics of age, weight, type of shoe, and whether or not they used the handrail. Most occupants' symbols only appear on two data points; drawing attention to their area of relevance. Symbols down the length of a data series indicate that the occupant had difficulties during the majority of their stair descent.

Pink-edged = occupant was overtaken by a few people

Blue-edged = occupant was significantly overtaken. They probably rested off camera

Orange-edged = occupant rested or paused on camera

Green-edged = occupant held people up

Black-edged = occupant stumbles

White-edged = occupant has/might have some health issue

Yellow-edged = occupant deserves additional comment. See section below

Slim = BMI< 25 Overweight = BMI > 25 < 30 and Obese = 30+

Female

60 years +

X slim, business shoes, no handrail

X slim, business shoes, handrail

X overweight, business shoes, no handrail

X overweight, business shoes, handrail

35 – 59 years

slim, high heels, handrail

slim, flat sandals, handrail

slim, sports shoes, no handrail

slim, sports shoes, handrail

slim, business shoes, no handrail

slim, business shoes, handrail

overweight, slight heel, no handrail

overweight, slight heel, handrail

overweight, business shoes, no handrail

overweight, business shoes, handrail

overweight, sports shoes, no handrail

overweight, sports shoes, handrail

overweight, flat sandals, handrail

overweight, high heels, handrail

obese, sports shoes, no handrail

obese, sports shoes, handrail

obese, flat sandals, handrail

obese, business shoes, handrail

obese, business shoes, no handrail

vision impaired

Less than 35 years

slim, sports shoes, used handrail

slim, sports shoes, no handrail

slim, slight heel, handrail

slim, slight heel, no handrail

slim, business shoes, handrail

slim, business shoes, no handrail

- Young, slim, sandals, no handrail
- overweight, business shoes, handrail
- overweight, business shoes, no handrail
- overweight, sports shoes, handrail
- overweight, sports shoes, no handrail
- overweight, slight heel, no handrail
- slim, high heels, handrail
- slim, heels, no handrail
- slim, flat shoes, no handrail
- obese, high heels, handrail

Male

60 years +

- overweight, business shoes, no handrail
- overweight, business shoes, handrail
- overweight, sports shoes, handrail

35 – 59 years

- slim, business shoes, no handrail
- slim, business shoes, handrail
- overweight, business shoes, no handrail
- overweight, business shoes, handrail
- overweight, sports shoes, handrail
- overweight, sports shoes, no handrail
- slim, sports shoes, no handrail

slim, sports shoes, handrail

Less than 35 years

slim, business shoes, no/light handrail

slim, business shoes, handrail

slim, flat/sports shoes, handrail

slim, sports shoes, no handrail

Occupants needing additional comment

Building M1 Trial Evacuation: This occupant is obese and carries a large number of bags. She takes a while to get out of the doorway at level 6, but keeps up with the flow of occupants evacuating the building. She is descending Stair A.

Building M5 East Stair and IPAQ survey: This man dropped back to talk with friends from his own floor. He is not having difficulties.

Building M5 East Stair and IPAQ survey: This man was interested in writing on the piece of paper in his hand. He would rush ahead and then try to write on landings. He had arguments with a warden, who wanted him to evacuate with everyone else.

Building M6, stair 2, chart 3 and IPAQ Survey: This female person and her friend (less than 35 years old, slim, not using the handrail) must have rested on a landing out of sight of a camera; they also rested on level 6. She appears to be having difficulty and health condition not known.

This person is carrying a stroller and could well be impeding his own view of the stairs. Manchester Clean Stair.

Observers' Comments

Observer comments are generally recorded on separate spread sheets because of lack of space on stair descent charts. These comments apply as part of the triangulation.

The M6 stair descent charts also have observers' comments on them. The observers followed a group of occupants down the stairs and recorded how many occupants there were on the stair in front of them and how many of those occupants were using the handrail. The observers' descents are marked in red.

Observer's comment: occupants on stair

1

2

3

4

5

6

10

Observer's comment: occupants using rail

0

1

2

3

* 4

* 5

* 6

Note: Other observer comments are presented after triangulation study extrapolated from the observer spread sheets.

DVD File Management

The Working File Hierarchy for the 2008-2010 Case Study Buildings M1-M6 may be found in the DVD entitled 2008-2010 Case Study Working Data File and is as follows:

Folder 1: BUILDING M1:

Sub Folder 1-Stair A/ stair 1

1-Presentation Data

1-***Stair Descent***

1-Descent Chart.doc

2-***Velocity and Density***

1-Final Level.doc

2-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-Observation Data

1-Descent Data.xls

2-Density Data.xls

Sub Folder 2-Stair B/ stair 2

1-Presentation Data

1-***Stair Descent***

1-Descent Chart.doc

2-***Velocity and Density***

1-Final Level.doc

2-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-<u>Observation Data</u>

1-Descent Data.xls

2-Density Data.xls

<u>Folder 2-BUILDING M2 (UAE):</u>

No details recorded observation logs included with text.

<u>Folder 3-BUILDING M3:</u>

Sub Folder1-Clean Stair/ stair 1

1-<u>Presentation Data</u>

1-***Stair Descent***

1-Descent Chart.doc

2-***Velocity vs Density***

1-Level 5.doc

2-Level 10.doc

4-Combined.doc

5-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-<u>Observation Data</u>

1-Descent Data.xls

2-Density Data.xls

Sub Folder 2-Dirty Stair/ Stair 2

1-<u>Presentation Data</u>

1-***Stair Descent***

1-Descent Chart.doc

2-***Velocity vs Density***

1-Level 4.doc

2-Level 8.doc

3-Level 11.doc

4-Level 16.doc

5-Combined.doc

6-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-<u>Observation Data</u>

1-Descent Data.xls

2-Density Data.xls

<u>Folder 4-BUILDING M4</u>

Sub Folder 1-Basement Stair/ |Stair 1

1-<u>Presentation Data</u>

1-***Stair Descent***

1-Key Chart.doc

2-Chart 1.doc

3-Chart 2.doc

2-***Velocity vs Density***

1-Level 7.doc

2-Level 11.doc

3-Level 17.doc

4-Combined.doc

5-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-Observation Data

1-Descent Data.xls

2-Density Data.xls

Sub Folder 2-Main Stair/ Stair 2

1-Presentation Data

1-Stair Descent

1-Key Chart.doc

2-Chart 1.doc

3-Chart 2.doc

2-Observation Data

1-Descent Data.xls

Folder 5-BUILDING M5

Sub Folder1-East Stair/ Stair 1

1-Presentation Data

1-***Stair Descent***

1-Descent Chart.doc

2-***Velocity vs Density***

1-Level 5.doc

2-Level 10.doc

3-Level 15.doc

4-Combined.doc

5-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-Observation Data

1-Descent Data.xls

2-Density Data.xls

Sub Folder 2-West Stair

1-Presentation Data

1-***Stair Descent***

1-Key Chart.doc

2-Chart 1.doc

3-Chart 2.doc

2-***Velocity vs Density***

1-Level 4.doc

2-Level 7.doc

3-Level 14.doc

4-Combined.doc

5-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-<u>Observation Data</u>

1-Descent Data.xls

2-Density Data.xls

<u>Folder 6-BUILDING M6</u>

Observers' Descent Speeds

Handrail Use

Sub Folder1-Stair 1

1-<u>Presentation Data</u>

1-***Stair Descent***

1-Key Chart.doc

2-Chart 1.doc

3-Chart 2.doc

4-Chart 3.doc

5-Chart 4.doc

2-***Velocity vs Density***

1-Level 14.doc

2-Level 20.doc

3-Level 22.doc

4-Combined.doc

5- Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-Observation Data

1-Descent Data.xls

2-Density Data.xls

Sub Folder 2-Stair 2

1-Presentation Data

1-***Stair Descent***

1-Key Chart.doc

2-Chart 1.doc

3-Chart 2.doc

4-Chart 3.doc

5-Chart 4.doc

2-***Velocity vs Density***

1-Level 12.doc

2-Level 15.doc

3-Level 23.doc

4-Level 25.doc

5-Combined.doc

6-Velocity and Density over Time.doc

3-***Density***

1-Density Chart.doc

2-Observation Data

1-Descent Data.xls

2-Density Data.xls

Sub Folder 3-Stair 3

1-Presentation Data

1-***Stair Descent***

1-Descent Chart.doc

2-***Velocity vs Density***

1-Level 6

2-Velocity and Density over Time

3-***Density***

1-Density Chart

2-Observation Data

1-Descent Data.xls

2-Density Data.xls

NOTE: The DVD or electronic data is available for the reader to interrogate the descent charts as they can be enlarged as required. The data used to develop the stair descent chart is also shown. It is available for further analysis if required in the future. The schedules included with the next section use data abstracted direct from the Excel® Spreadsheets.

Triangulation

The main purpose of triangulation in the 2008-2010 Case Study is to enhance and challenge the results of the surveys for M1-M6. Many of the results from the survey could be challenged by those wary of the Case Study Method (Flyvbjerg, 2006) because they are based on self reporting where measures such as mass or fatigue can be under or over reported by the respondent. Other responses are based on the respondent's perception of the stair pitch or steepness which may not correspond with those of the safety practitioner or the results of biomechanics experiments. The differences between the responses need to be highlighted and discussed.

The triangulation process is described in Chapter 4 but also satisfies the requirements of pluralist research as described by Amaratunga et al (2002) for studies in the Built Environment. Not all the variables analysed in Sections 7.2-7.5 will be triangulated but rather the critical extrinsic and intrinsic factors identified in Figure A51 below:

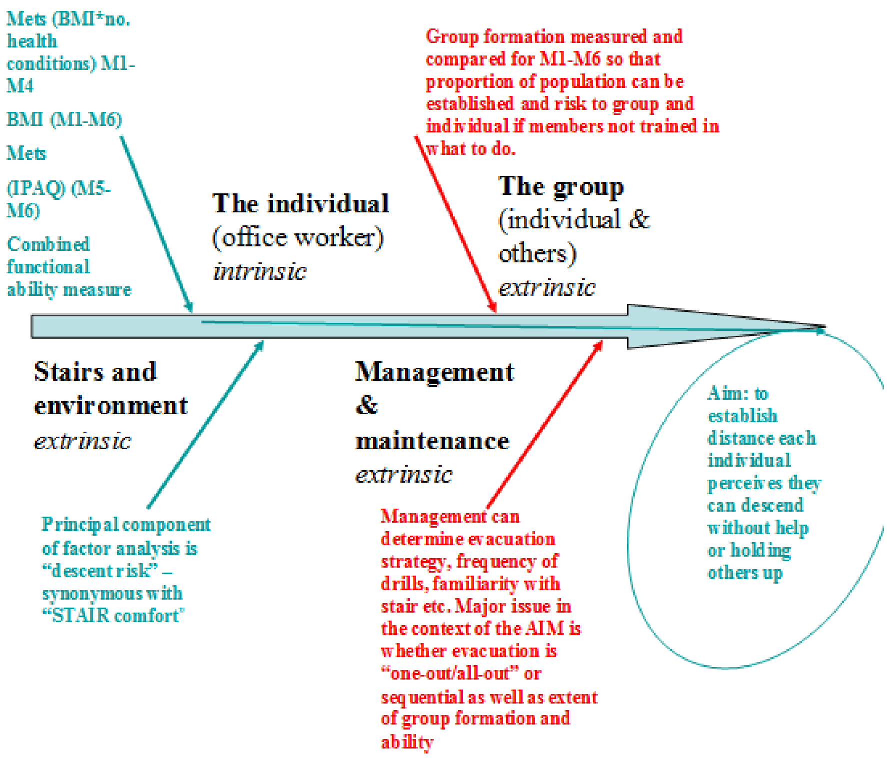


Figure A51: Framework showing key factors for triangulation

Triangulation schedules have been prepared for Buildings M1-M6 as follows:

- BMI Classifications per level commenced evacuation per building per stair compared with descent speed (minimum, mean and maximum).
- Number of health conditions or level of functional limitations per level commenced evacuation per building per stair compared with descent speed (minimum, mean and maximum).

- Group formed and conditions in stairs compared with video observations, densities measured and observer comments.

Most of this aspect of triangulation dealing with measured data and occupant response will be via discussion referring to measured assessments and ratings in tables for each building.

The findings will then be used to filter the outcomes from Chapters 6 and 7 which include the Focus Groups. The fall risk analysis will be used to complete the Triangulation Sections.

*Structure of Section 7.6 and Cross Referencing with Chapter 7.6***.**

The structure of A7.6 is as follows:

- Generally (A7.6.1).
- Description of creation of DVD Files in addition to A7.6.1(A7.6.2).
- Measured Data and Ratings for M1-M6 (A7.6.3).
- Triangulation (A7.6.4).
- Discussion of combined findings (A7.6.5).
- Concluding remarks (A7.6.6).

A7.6.2 Description of Creation of DVD/ Electeronic Data Files

The data for each stair in Buildings M1-M6 is split into presentation data and observation data. This section is included so that the reader understands the working of the spread sheets and can therefore interrogate the data as required.

The presentation dataset contains stair descent charts, velocity vs density scatter plots, and density charts. On the stair descent charts every occupant is represented by a single line or data series; the colour of the data series depends on the level the occupant originated from. Observers are always marked in red, regardless of the floor of origin. There are a number of symbols on most of the stair descent charts which are described earlier. Black arrows indicate the first and last occupants that emerged from each level. The density charts show the densities of occupants on certain levels every thirty seconds. Generally, the levels measured include a lower level, a middle level, and an upper level. Some stairs have less data than others. This is due to difficulties encountered in extracting data from the video images e.g. Building M6. The velocity vs. density plots show the velocities (usually the speed an occupant travelled at from that level to the next recorded level) plotted against the corresponding densities. These show the relationship between density and velocity. There is also a chart for each stair in the velocity vs. density folders that show both the densities and velocities over time, in the same format as the density charts.

The observation dataset contains the actual data and images that the presentation data is graphed from. The stair descent data and the density data are located in this part of the dataset. There are two different formats of stair descent data due to different techniques used to abstract the original data from the video images. The M6 building data is arranged so that every row represents one occupant, while the other buildings' data has one occupant per column. Each occupant has some key features recorded, e.g. shirt colour, hair colour and style etc., to enable recognition of the occupants as they pass the cameras.

In the M6 observation spreadsheets, for each floor level, there are four columns of times. The first is the video timestamp when each individual passes the checkpoint for that level, the second is the normalised time from a certain point consistent in all videos, and the third is a calculation column enabling the time shown in the fourth column to be assessed. The fourth column records the actual time (e.g. 11:33:05am) that each occupant passes the checkpoint.

For the other buildings, for each floor level, there are two rows of times. The first row shows the video timestamp and the second shows the normalised time. The real times used in the graphs are not immediately evident on these spreadsheets. The easiest way to derive the real time for any video timestamp is to locate the cell in which the equivalent time to 0:00 is found, usually in cell A2. Using this, the real times can be obtained by adding the base real time in A2 to the time in the second row.

The data spreadsheets for all buildings, except for Kent, are split into two parts: the top part is of most interest as it shows the data from the videos; the bottom part is the data from which the descent charts are graphed.

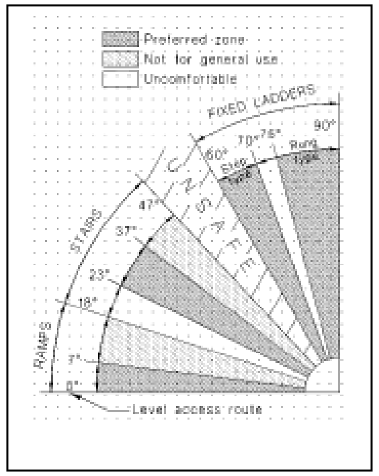
A7.6.3 Measured Data and Assessments

Schedules of the measured data are already presented in Chapter 4. These schedules include the ratings on a set scale for ease of comparison with the survey data. This section is subdivided into a number of subsections according to the building being discussed. The measurements and associated ratings are presented in Table A121 to Table A124 where the rating scale used is as follows is 5 for the best and 1 for the worst. Table cells with a neutral highlight are actual measurements in millimetres.

The two exemplar buildings from the Exploratory Case Study are included to complete the triangulation process. Table A121 to Table A124 contain a number of variables that need to be reduced for the initial comparison. Principal Component Factor Analysis was used (SPSS V16) to achieve this end but the data needed to be aggregated to carry out the analysis (Child, 2006 and Kline, 2008). The output presented in Table A125 assumes a certain amount of generalisation across the buildings but the groupings and ordering of the factors around “Principal Components” provide a clearer framework for triangulation with the equivalent perceptions of the occupants who responded to the survey for buildings M1-M6.

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
Ex3.1	34	4	260	2	185	2	36	1	2	1020
Ex3.2	34	4	260	2	185	2	36	1	2	1020
Ex7.1	20	2	250	1	190	1	37	1	1	1020
EX7.2	20	2	250	1	190	1	37	1	1	1020

Stair geometry and width



Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
Ex3.1	34	1	2	200*	1
Ex3.2	34	1	2	200*	1
Ex7.1	20	1	2	123*	2
EX7.2	20	1	2	123*	2

Handrails provision for support (* *rectangular section handrail*)

Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
Ex3.1	34	151	4	1	4	3	3
Ex3.2	34	151	4	1	4	3	3
Ex7.1	20	49	1	1	4	2	3
EX7.2	20	49	1	1	4	2	3

Stairway visibility

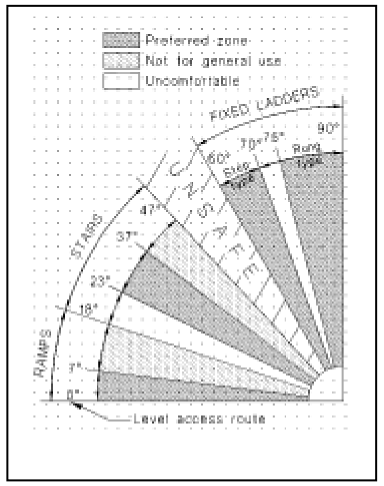
Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
Ex3.1	34	5	3	3	4	4	1850	4	2	5	4
Ex3.2	34	5	3	3	4	4	1850	4	2	5	4
Ex7.1	20	5	5	5	1	4	1520	4	2	3	4
EX7.2	20	5	5	5	1	4	1520	4	2	3	4

Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

Table A121 ***EXPLORATORY CASE STUDY – STAIR ENVIRONMENT INPUT – BUILDINGS 3 AND 7 (cells with neutral highlighting are actual measurements – Others are rating scales of 1-5 with 1 being the worst and 5 the best – for user testing)***

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
m1-1	10	5	280	3	175	2	32	3	1	1020
m1-2	10	5	280	3	175	2	32	3	1	1020
m2-1	36	4	300	4	175	2	30	3	4	1020
m2-2	36	4	300	4	175	2	30	3	4	1020

Table – Stair geometry and width



Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
m1-1	10	2	5	40	4
m1-2	10	2	5	40	4
m2-1	36	5	4	60	2
m2-2	36	5	4	60	2

Table – Handrails provision for support

Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
m1-1	10	50	2	2	4	3	2
m1-2	10	50	2	2	4	3	2
m2-1	36	<100	5	1	1	1	1
m2-2	36	<100	5	1	1	1	1

Table – Stairway visibility

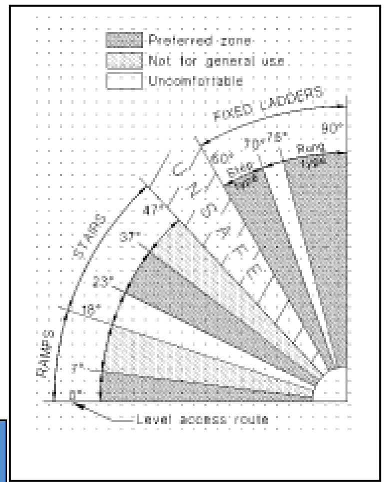
Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
m1-1	10	5	5	3	5	4	2975	4	4	1	4
m1-2	10	5	5	3	5	4	2975	4	4	1	4
m2-1	36	5	5	3	4	1	1750	4	2	1	5
m2-2	36	5	5	3	4	1	1750	4	2	1	4

Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

Table A122– 2008-2010 CASE STUDY – STAIR ENVIRONMENT INPUT – CYCLE 1 – BUILDINGS M1(Christchurch) and M2 (UAE) (*cells with neutral highlighting are actual measurements – Others are rating scales of 1-5 with 1 being the worst and 5 the best – for user testing)*

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
M4-1	26	5	260	2	150	5	30	3	4	1000
M4-2	26	5	260	2	150	5	30	3	4	1000
M3-1	17	3	247	1	190	2	38	1	3	975
M3-2	17	3	247	1	190	2	38	1	3	960

Stair geometry and width



Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
M4-1	26	2	5	40	4
M4-2	26	2	5	40	4
M3-1(dirty)	17	4	2	12/60/25*	2
M3-2(clean)	17	4	2	12/60/25*	2

Handrails provision for support *(*rectangular handrail sections)*

Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
M4-1	26	<100	2	2	4	4	4
M4-2	26	<100	2	2	4	4	4
M3-1(dirty)	17	50	2	2	5	1	4
M3-2(clean)	17	100	3	4	3	3	4

Stairway visibility

Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
M4-1	26	5	5	4	5	4	1650	3	2	4	3
M4-2	26	5	5	4	5	4	1650	3	2	4	3
M3-1(dirty)	17	4	1	2	4	3	1520	2	3	1*	4
M3-2(clean)	17	4	5	3	4	4	1520	5	5	4	5

Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

** rated as 1 because extremely dirty prior to evacuation – was cleaned on day so that rating would alter - perception*

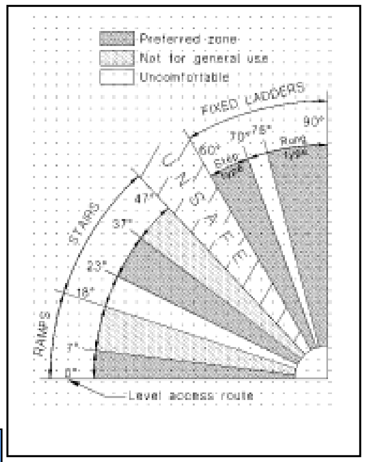
Table A123:2008-2010 CASE STUDY – CYCLE 2 –Buildings M4 and Building M3 (*cells with neutral highlighting are actual measurements – Others are rating scales of 1-5 with 1 being the worst and 5 the best – for user testing)*

Bldg/Stair	No.Storey	No.Turns	Treadsize	Treadsafe	Riserht.	Risercomf	Stairsteep%	Strsteepcon	Stairuniform	Clearwide
m5-1	18	1	270	2	170	2	32	3	3	1065
m5-2	18	1	270	2	170	2	32	3	3	1065
m6-1	32	1	260	2	190	2	37	1	5	1000
m6-2	32	1	260	2	190	2	37	1	5	1040
m6-3	32	1	260	2	190	2	37	1	5	1040

Table – Stair geometry and width

Bldg/Stair	No.Storey	Hdrlprovide	Hdrleffic.	Hdrldiam	Hdrlgrasp
m5-1	18	4	1	R	1
m5-2	18	4	1	R	1
m6-1	32	4	2	50	3
m6-2	32	4	2	50	3
m6-3	32	4	2	50	3

Table – Handrails provision for support *(R= irregular rectangular section)*



Bldg/Stair	No.Storey	Illuminat	Illumconf	Stairleg	Hdrlleg	Contrast	Nosingcon
m5-1	18	100	3	2	2	3	4
m5-2	18	100	3	2	2	3	4
m6-1	32	250+	5	4	2	2	4
m6-2	32	250+	5	4	2	2	4
m6-3	32	250+	5	4	2	2	4

Table – Stairway visibility

Bldg/Stair	No.Storey	Doorsencr.	Obstruct	Comfort	Wellvent	Orientate	Fallheight	Slipres.	Familiar	Manmgt.	Rest
m5-1	18	5	5	1	1	3	1050	2	4	5	3
m5-2	18	5	5	1	1	3	1050	2	4	5	3
m6-1	32	1	5	2	1	4	1560	5	3	5	2
m6-2	32	5	5	2	2	4	950	5	3	3	4
m6-3	32	1	5	2	2	4	1560	5	3	3	2

Table – Overall Comfort, Ventilation, Orientation, Falling factors, Familiarity, Management and Resting Space

TableA124:2008-2010 CASE STUDY – CYCLE 3 – Building M5 (Wellington 2) and Building M6 (Sydney) (*cells with neutral highlighting are actual measurements – Others are rating scales of 1-5 with 1 being the worst and 5 the best – for user testing)*

Variable	1 (8)*	2 (7)*	3 (4.8)*	4 (3)*	5 (2.8)*	6 (2.1)*
Tread width			0.7			
Riser perceptive	0.9					
Stair pitch	0.8					
Uniformity		0.7				
Handrail ffp	.77					
Handrail dia						.8
Illumination				93		
Step legibility					.89	
Nosing sharp		0.9				
Confidence	.76					
Wide well	.71					
Orientation			.84			
Maintenance			.83			
Space for rest				76		
Distance				83		
Tread width/ shoe ratio			.74			
Riser height	.94					
Width						.92
Falling height		0.93				
COMPONENT DESCRIPTION	**DESCENT RISK**	**FALLING HAZARD**	**STEPPING CONFIDENCE**	**CLEAR PATH AND SPACE TO REST**	**STEP VISIBILITY**	**SPACE TO SAFELY MOVE**

*Factor analysis of data from observer template – selection value ≥ 0.7. *Eigenvalues selected as >2.*

Table A125: FACTOR ANALYSIS Buildings 3,7 and M1-M6: Observed and Measured Factors/ Variables.

1-3 = descent risk

Table A125 reduces 19 factors to some 6 components. The eignevalues for each component vary from 8.0 to 2.1 and caters for approximately 80% of the variance. The cut off values for the individual factors “adhering” to each component exceeds 0.7 which demonstrates the strength of their relationship to each component. The nominated “cut-off values” are in line with those recommended in the literature (Child, 2006 and Kline, 2008).

Variable	Component	
	1(7.8)*	**2(4)***
handrail easy to find		**.948**
first step easy to find		**.970**
each step easy to find		**.972**
Last step easy to find		**.970**
stair gradient	**.839**	
treads too small	**.826**	
too many flights of stars’	**.881**	

Reinforced via focus group comment about continuous downward spiral, narrow treads in relation to size of feet, width of well (rich views) and relation to fear of falling to health impacts such as dizziness/ vertigo and safe feelings. .

Table A126: Perceptual Factors (STAIR).

Comparison of Factor Analyses Output – Basis of Triangulation with observed and measured data.

It is difficult to directly compare the output from two different sets of factor analyses but the first principal components from each of the output schedules coincide reasonably well on an overall theme of "Descent Risk". It is reasonable to extend the meaning of descent risk to include "Falling Risk" and "Stepping Confidence" (see Table A125 where components 1-3 are linked together in a "red frame". This links up extremely well with "narrow treads and stair gradient" in Table A126 when these are linked directly with comments from the Focus Groups about the "downward spiral" which include agoraphobic distractions such as the open well and number of turns per level[7]. Distance only features in Component 4 and yet this was found by Peacock et al (2009 and 2012) to be one of the major predictors of descent speed. The remaining factors to be grouped together in the second component in Table A126 are all to do visibility and support as shown in Chapter 7. If components 4-6 are aggregated together then they too can be seen to be concerned with visibility, support and orientation. Focus group comments concerned with distance and places to rest and changes in frequency of responses increasing with distance traversed (evacuation floor number in survey) triangulate reasonably well with the observed and measured factors. Triangulation on visibility includes legibility of steps both in terms of marking and illumination. Focus Groups were concerned about their view of the nosings being obstructed by others which would be improved by having wider stairs.

[7]Also referred to indirectly by Archea et al (1979), Templer (1992), and Johnson and Pauls (2011) referring to Wright and Roys (2008).

With reference to Table A121 to Table A124 each of the factors will be discussed in turn in the next section under the same group headings as those listed under each table.

Observed and measured data – "STAIR" and "Management". Stair geometry and width

Chapter 6 of the Thesis shows a decrease in the risk of falling of only .012 for the range of treads measured for the exemplar buildings 3 and 7 and M1 – M6 (250-300mm). Treads measuring between 195 and 245mm increase in risk by a further 0.14[8].

Treads measured 260mm and 250mm respectively in Buildings 3 and 7. The rating in Table A121 is 2 and 1 respectively. Approximately 30% of the occupants in these buildings were concerned. Given the mean length of a male foot at that time was 300mm (MacLennan, 2011) this confirms why a significant number of the population would have been concerned at the time. The pitch of the stairs was 36^0 and 37^0 respectively borders on the characteristics of service stairs. Only about 7% of the occupants were concerned. This does not really correspond but did change over 30 years.

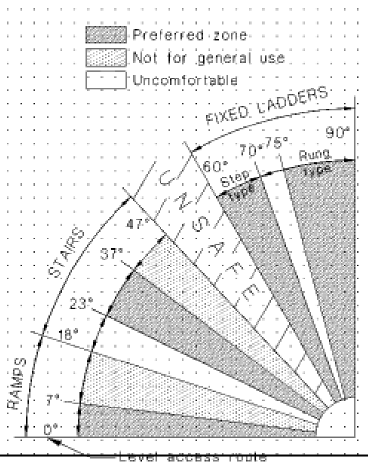


Figure A52: Stair Chart AS/D1 NZ Acceptable Solutions

[8] *Log_{10} y (width of tread) = -35.03ln(x)+144.73 where x = level of risk* extrapolated from study by Johnson and Pauls (2011).

The treads in M1 measured 280mm. The mean shoe length was 289mm and yet the percentage of population who were concerned was 27.7% which is the same as Buildings 3 and 7. The pitch of the stairs is some 32^0 which is well within the preferred zone according to Figure A52 (rating = 3) and yet there is still 21% of the population that are concerned. It would appear that the findings of Roys (2006) apply for the 300mm tread. The situation in M1 cannot be transferred to M2. The mean shoe length is 294mm with a maximum of 352mm so that with a tread width of 300mm a percentage of 45% of the occupants is extremely difficult to explain. Once again the response could be explained by the increased distance (36 floors) and the hot conditions (+40^0C).

The treads in M3 vary from 245 to 250mm which have the worst rating out of all the buildings. This corresponds with the sudden increase in the level of risk (Johnson and Pauls, 2011) for the 245mm tread. The mean shoe length is 281mm which should trigger a concern. Only 26% of the occupants were dissatisfied. The pitch of the stairs was 38^0 which is greater than the preferred zone in Figure A52 (rating = 1) and 23% of the occupants were concerned. The triangulation is reasonable.

The treads in M4 measured 260mm. The mean shoe length was 289mm with a maximum of 319mm. 21% of the occupants were concerned which is significant and is therefore explained. The risers were only 150mm so that the pitch was some 30^0 which is well within the preferred zone of Figure A52 (rating = 3). Only 9% of the population were concerned with the pitch. The response triangulates reasonably well. The treads in M5 measured 270mm. The mean foot length was 290mm with a maximum of 330mm. Only 18% of the population were concerned. This compares favourably with M4. Occupants were moving at a slower speed as is demonstrated in section 7.6.4 so that this may have slightly mitigated the concern. The pitch was some 32^0 which falls within the preferred region of Figure A52 (rating = 3) and 11.7% of the occupants were concerned.

The reason for this decrease is seen to be the relatively slow descent speed which lessened the impact of the "downward spiral[9]".

The treads in M6 measured some 260mm. The mean foot length was 280mm with a maximum of 335mm. The resultant overhang is in excess of 25mm and the Focus Groups from this building voiced their concern about the 250mm tread. There was an expected increase in percentage of concerned occupants (31%). The slope of the stairs was similar to M3 being 36^0 which is just within the preferred zone of Figure A52 (rating = 1). The percentage of concerned occupants was 28% which triangulates well.

Uniformity was an issue in Buildings 3 and 7 where the rating was between 1 and 2. On average only 8.5% of the occupants were concerned. M1 was similar to 3 and 7 in that 12% were concerned. In M2 where the rating was 4 only 4% were concerned. M3 and M4 had ratings of 3 and 4 which were reflected in 1.9% and 0% of the occupants who were concerned. M3 and M4 triangulate well. M5 and M6 were rated even higher and only had an average of 4.5% of the occupants who were concerned. Overall the triangulation follows a weak pattern of agreement.

Handrails – provision for support

In every case the occupants confirmed that the handrails were easy to find. This did not accord with the observations which downgraded ratings for contrast, number and graspability. The lack of agreement can be explained by observation and the comments made by focus groups. Observers descending with the occupants showed that approximately 25% of each group they were following used the handrail and that this increased to 50% plus prior to reaching the lower levels (e.g. M6 and M3). The focus group comments reflect the

[9] Output from the Focus Groups.

findings of Reeves et al (2008a) about individuals gaining in confidence by loosely holding the handrail. The author's case study shows the opposite end of the spectrum where someone relies heavily on handrails and their graspability on each side of flight to mitigate any perturbations. This reflects the findings of Maki et al (1998).

Stairway visibility

87% of the occupants in Building 3 and 80% in Building 7 had no problem with visibility which reflects a lighting level of 50+ lux. Building 7 had severe shadows affecting stair legibility at various points but this was not reflected in the responses. The illumination levels in M1-M6 were all reasonable. In M1 and M2 the stair legibility was poor. There were a significant percentage of occupants who were concerned in each case and yet this did not include the first step in each flight. In M1 the percentage peaked at 25%. M2 only peaked at 10.4% and yet the stairs were virtually illegible (white). This building is where the lack of step definition was one of the triggers for one of the falls. Concern for step definition was also expressed by the focus groups especially in terms of those with reduced vision with poor depth perception.

M3 and M4 had a reasonable overall level of contrast between vertical and horizontal surfaces with marked nosings. Less than 3% of the occupants were concerned. M3 and M4 triangulate reasonably well although the occupants were familiar with the steps because of their past evacuation experience.

M5 triangulates well with ratings of 3 and 4 and this is reflected in a low rate of concern in responses of some 3%. M6 had grey walls and grey treads but the nosing were marked in yellow. These were still perceived as "white-out" conditions by some as indicated by the focus groups and yet only 6% of the respondents were concerned. The marking of the nosings was a direct response of management to occupant feedback. The pattern of triangulation was quite weak and yet M2 did not match at all. It is no coincidence when visibility is exacerbated by distance and the constant "downward spiral" that it would be the sites of one of the falls.

Overall comfort, ventilation, orientation, falling factors, familiarity, management and resting space

Each one of the buildings is discussed separately because of the number of related factors:

Buildings 3 and 7:

Overall comfort as measured by obstruction and door obstruction is satisfactory for each building and the occupants agree with this. The degree of ventilation is poor in 7 and reasonably good in 3. This was not reflected in the response where there virtually no concern whatsoever.

The level of management as reflected by their concern for procedures and maintenance is highly rated for Building 3 and 7 (5 and 3). The percentage of occupants who were concerned averaged some 14% which shows reasonable agreement.

Familiarity with the stairs is rated poorly for both buildings and yet this level of concern is not reflected in the occupant response.

Falling height is reflected in a height between landings. It would appear that a significant percentage were "somewhat concerned" being 25%-34%.

Resting space was provided in each building but there was no corresponding response.

Generally there is good agreement between occupant response and observed/ measured data for management and risk of falling.

Buildings M1 – M6:

Refer also Section A7.3 for additional triangulation comments.

Overall comfort is redefined as descent risk from the reduction of factors carried out in the factor analysis. “Too many flights” that reflects the focus group comment, “downward spiral”, is central to this factor, especially with an increase in distance traversed. The degree of correlation between the number of health conditions (stated separately in the correlation matrix in this chapter) across the entire group of buildings ($R>0.3$ and $p<.05$) along with fatigue confirms this measure.

In terms of triangulation the marked break in the overall pattern of responses is for M2 where distance, lack of ventilation and whiteout conditions exacerbate the locating of each step by the occupant, may cause these occupants to perceive that the treads are too narrow and stairs are too steep. The treads are 300mm and the pitch is only 30^0. Otherwise the level of comfort or descent risk concerned some 20% -30% generalised across M1, M3, M4 and M6 where the stair geometry was of concern (Johnson and Pauls, 2011 and Roys, 2006). M5 did not triangulate because of the slow descent speed which has already been discussed.

Management is measured by evacuation experience, use of a designated stair and also degree of crowding as relating to reduction in descent speed. There was a consistent pattern across all M1-M6 buildings of > 70% except for M2 which was 33.3%. This triangulates completely for all buildings especially given the malfunctioning of the fire alarm and the stair ventilation in M2. Also many of the levels in M2 refused to participate in the trial evacuation. This is also the building where there two falls recorded. The faster evacuation times reflected the adoption of a “one out-all out” or uncontrolled evacuation policy where the procedures were simple. This was also reflected in the experience level of the occupants (M1, M3, M4 and M5. The M6 strategy was sequential but had been regularly practiced as reflected in the experience rate of 85%. It was still more complex.

Familiarity with the stairs is rated as 4 for M1, 2 for M2, an average of 4 for M3, 2 for M4, 2 for M5 and 5 for M6. The response from the occupants shows evacuation experience resulted in >70% using the designated stair for the trial evacuations. The response for the designated stair exceeds 80% in most cases. The difference to this is M2 where the experience is 33% and the use of a designated stair is 50%. The triangulation here is pattern matched (Hak and Dul, 2009)

Resting space cannot be triangulated but applies given that response rates for “too many flights” correlates well with fatigue as indicated in Chapter 7. Video observations marked with the relevant symbol for M6 show people resting. This was observed in other buildings but could not be verified between the observer comments and video based data. Resting spaces were available in M1, M2, M3 (Stair 1), and Stair 2 in M6. The suggested layout is shown in Chapter 7. Possible space is provided where the rating is 3 and above in Table.

Falling height is reflected in a height between landings. This was not considered to be critical by occupants in their response concerning fear of falling (<6%) except for M4 where it increased to 14%. The falls produce an interesting dichotomy. Reducing the falling height by increasing the number of turns where the number of storeys exceeds 20 may be a problem given the pattern associated with distance reflected in M2 and M6 where the percentage of occupants reported fatigue, dizziness and vertigo as the impact of descent increased to an average of 43% and 25% respectively a good 100% increase over the other buildings. The above can be generalised across M1-M6 and is also consistent with comments from the focus groups. Provision of resting spots is therefore more suitable so that occupants can rest and reduce the risk of falling as they will not be so tired (Helbostad et al (2010).

Generally there is good agreement between occupant response and observed/ measured data.

The Group and Individual

The Group will not be discussed in this section as the comparison needs to a combination of observers' comments and interpretation from stair descent charts and then comparing these with group formation and stair condition responses. The risk of falling will also be discussed where the occupant has a condition that is associated with falling and has an apparent descent speed well in excess of those calculated/ measured for the Fuller Figure and Mature Age Focus Groups in Chapter 6.

The "Individual" or occupant was discussed in part in the previous section but the main triangulation discussion will be in the next section. See section A7.6.4 for further triangulations and discussion.

A7.6.4 Triangulation with Video Data

Framework

The development of the DVD data files/ spread sheets and graphs was outlined in Section A7.6.2. This section describes the triangulation method that will be used as an amplification of Chapter 3.

Base Stair Descent Spread Sheets and Charts

The path traces shown on the Descent Charts will be used to provide the following:

- Pattern matching (Hak and Dul, 2009) in terms of apparent "grouping" and merging of occupants
- Identification timeline for certain individuals who either delayed others, decided to rest, or who were identified as having some functional limitations and were descending at the same rate as the group they were

in at a velocity in excess of that recorded for the Fuller Figure and the Mature Age Focus Groups.

- Time line and stairwell location at points during the evacuation for the plotting of density and velocity data.

It should be noted that these stair descent charts have been used extensively by others over the period of study covered in this PhD Study (Pauls, 1977 and Peacock et al, 2012).

Density and Descent Velocity Graphs

Normally this type of data is presented in tabular form. This method has been only been used in the triangulation to record mean, minimum and maximum speeds and/or densities where the pattern matching technique (Hak and Dul, 2009) is not sufficiently accurate.

Three types of plots are presented for each building M1-M6:

- Density pattern over time (evacuation period) and the level concerned.
- Density and descent velocity patterns over time (evacuation period) and the level concerned.
- Linear regression of descent velocity vs. density in order to show the percentage variance that density can predict in descent velocity.

The linear regression analysis provides valuable information that can be used to qualify the influence of groups as highlighted in Chapter 6 and the descent ability of the occupants as compared with those of the members of the focus groups. Of special interest is the impact of density in M5 where 75% of the occupants reported high densities.

Triangulation Schedules

It was originally intended to locate a random selection of the survey respondents on the stair descent charts. This did not prove to be possible in the end due to the quality of some of the images and also the availability of suitable decoding resources. An alternate approach was adopted where schedules were prepared as shown in Table A127 below:

Body Mass Index	***Level No.***	***Stair 1 – No.***	***m/sec***	***Stair 2 – No.***	***m/sec***	***Comments***
Obese Class 3	11	2	first 0.47; last 0.40; av 0..42	1	first 0.33; last 0.41; av 0.37	**Different groups**

First occupant faster than last and *First occupant slower than last*

(#) Descent speed above benchmark – risk of falling

(*) Descent speed within benchmark – reduced risk of falling

No. Health Conditions	***Level No.***	***Stair 1 – No.***	***m/sec***	***Stair 2 – No.***	***m/sec***	***Comments***
0, 1, 2, or 3.	11	2	first 0.47; last 0.40; av 0..42	1	first 0.33; last 0.41; av 0.37	**Different groups**

First occupant faster than last and *First occupant slower than last*

(#) Descent speed above benchmark – risk of falling

(*) Descent speed within benchmark – reduced risk of falling

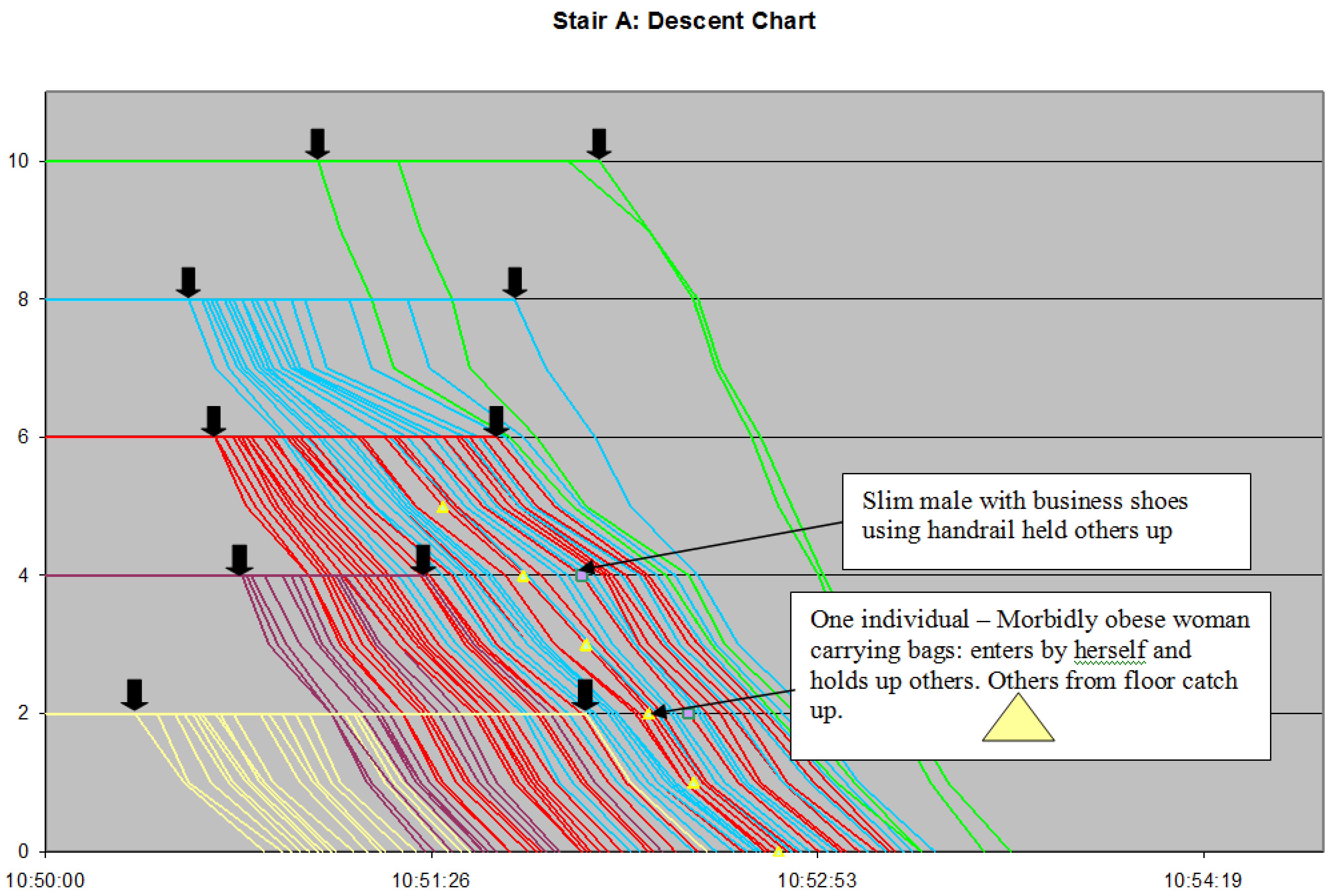
Table A127: Specimen Triangulation Schedules – BMI and Health Conditions – "The Individual"

An additional schedule was prepared in an abbreviated form to confirm or otherwise group formation. There is a further schedule shown in Table A128:

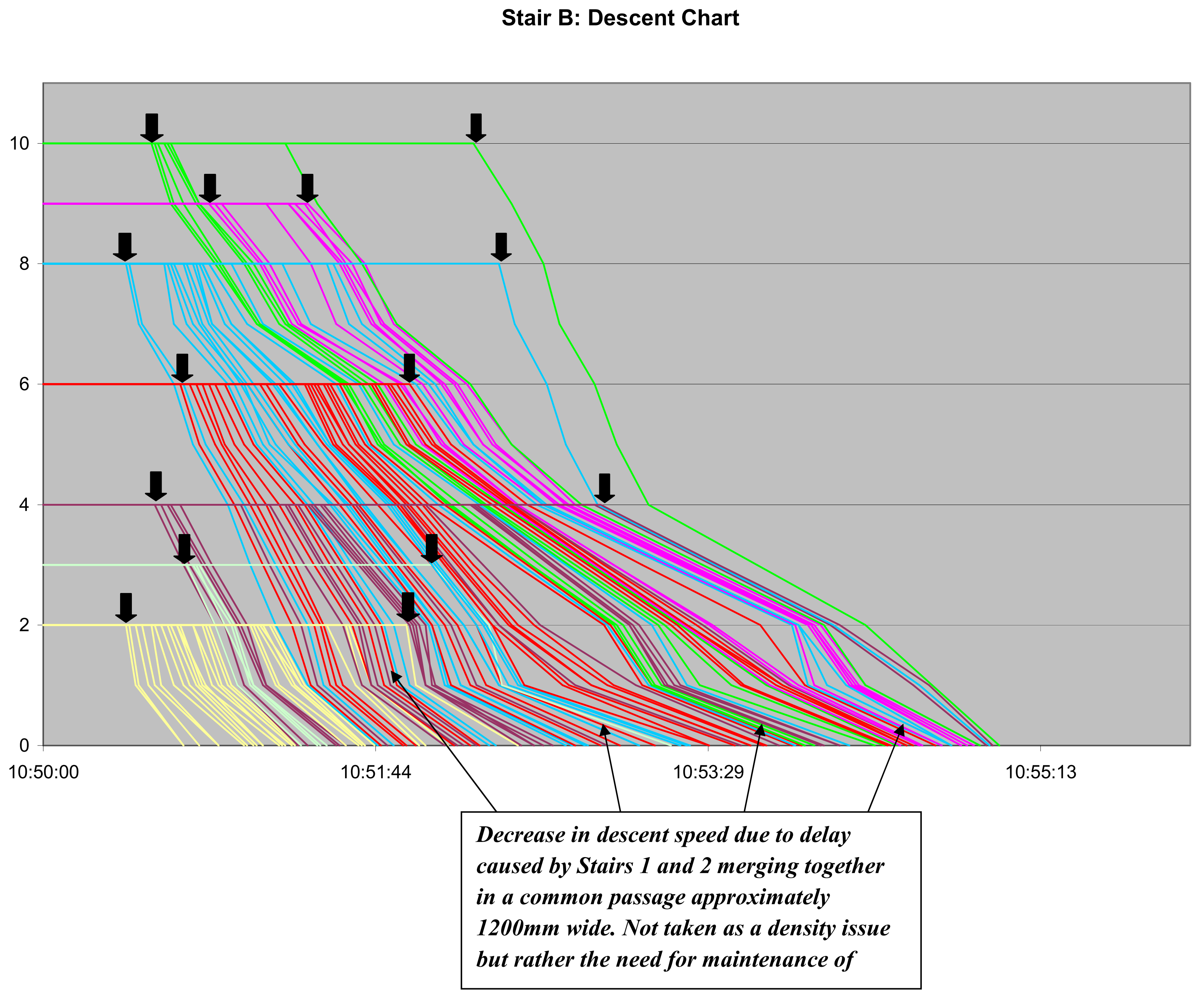
BUILDING M3: TRIANGULATION WITH GROUPS & DENSITY					
Conditions in Stair	**Level**	**Stair 1**	**Comments**	**Stair 2**	**Comments**
Alone	6	1	Verified	0	Not verified
	7	1	Not verified	0	No response
Few others around	1	4	Verified	0	Not verified
	2	3	Not verified	2	Not verified
	11	2	Verified	1	Verified
Crowded but moving	1	0	No response	1	Not verified
	17	1	Verified	2	Verified
Very crowded and slow	5	1	Verified	0	Not verified

Table A128: Specimen Triangulation Schedule – Groups and Density – "The Group and Management"

A7.6.4.2/M1 DESCENT CHARTS M1
Figure A53: M1 STAIR A = STAIR ONE

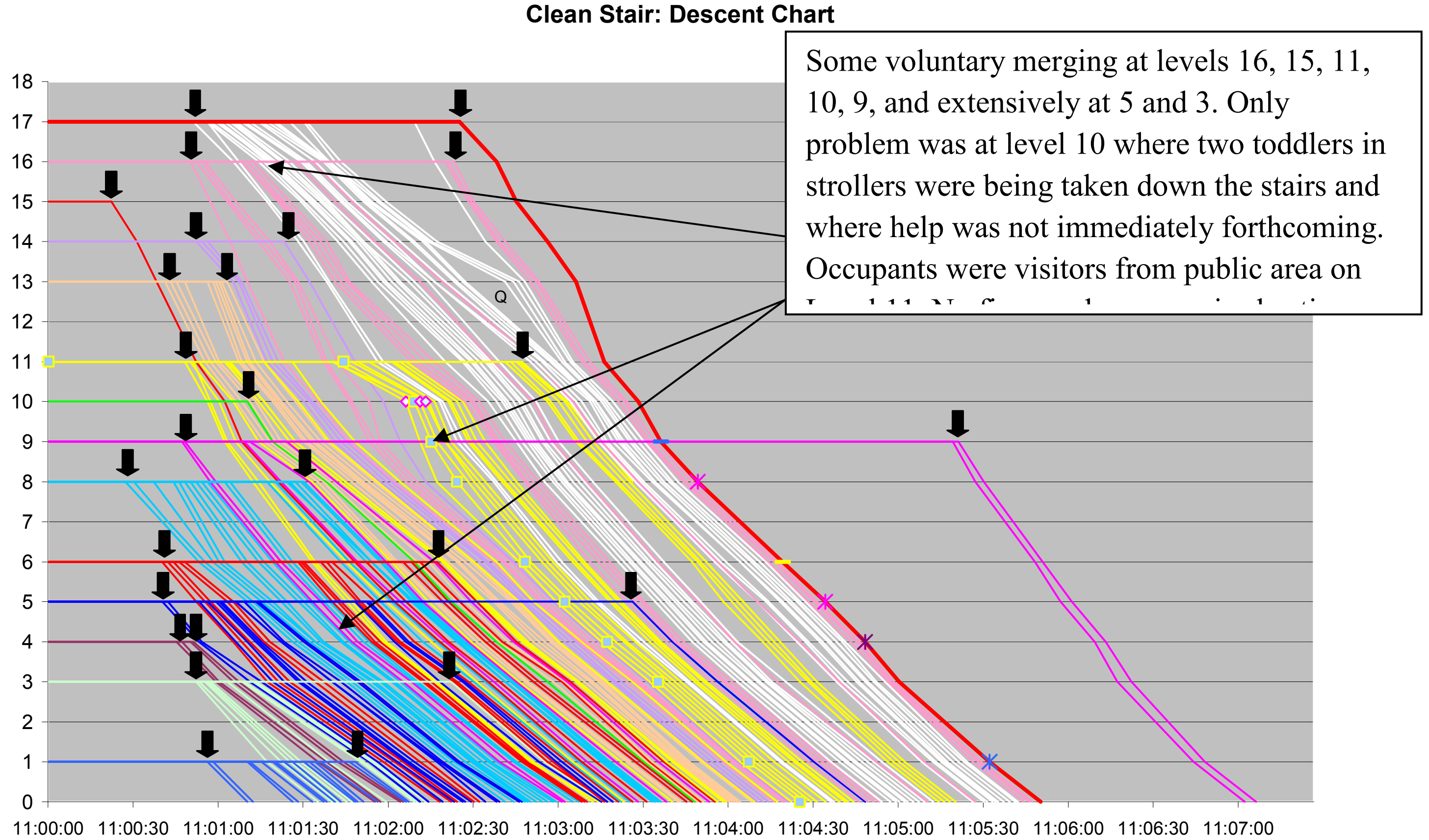


A7.6.4.2/M1 DESCENT CHARTS M1
Figure A54: M1 STAIR B = STAIR 2



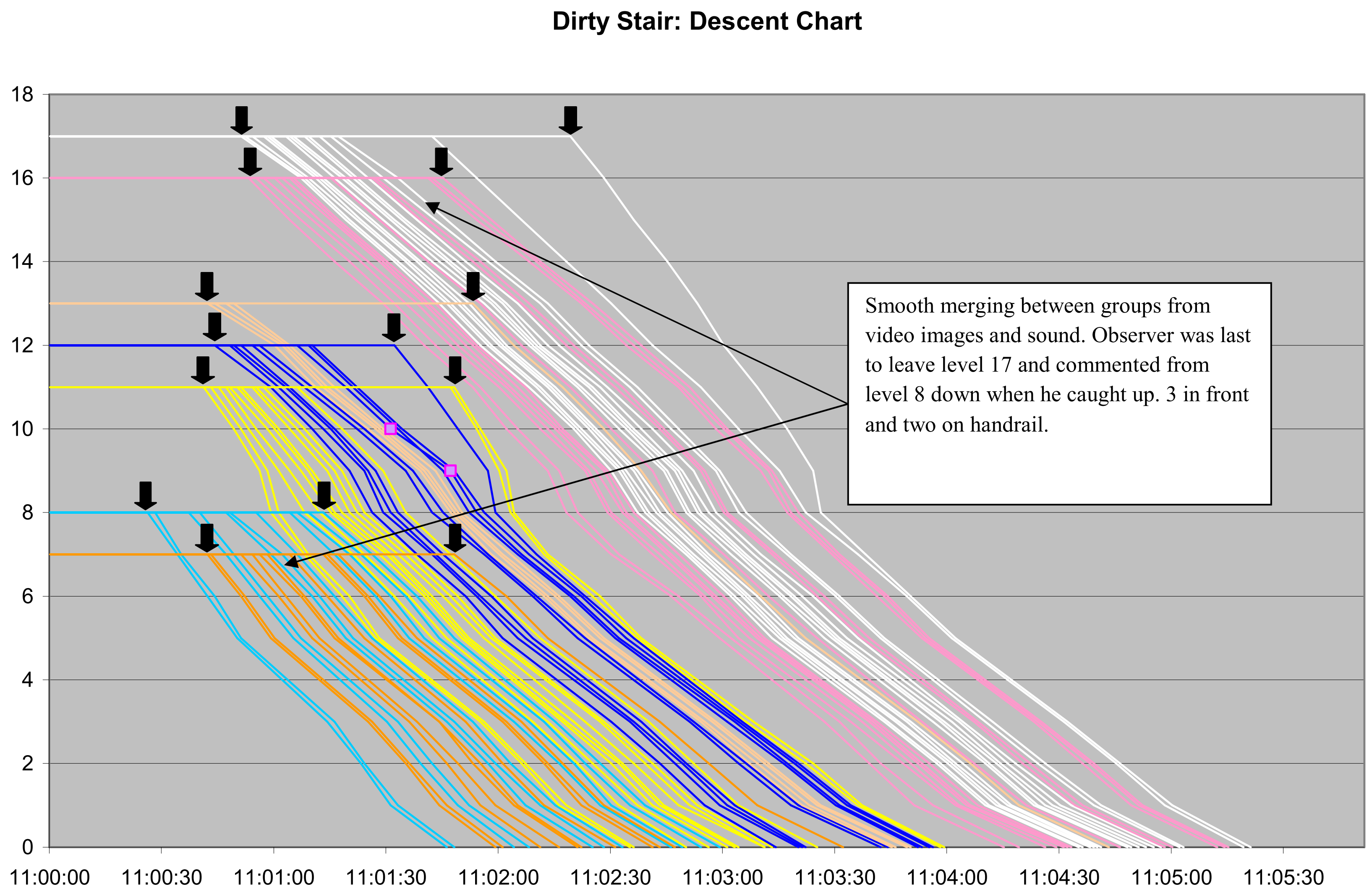
A7.6.4.2/M3 DESCENT CHARTS M3

Figure A55: M3 CLEAN STAIR = STAIR ONE



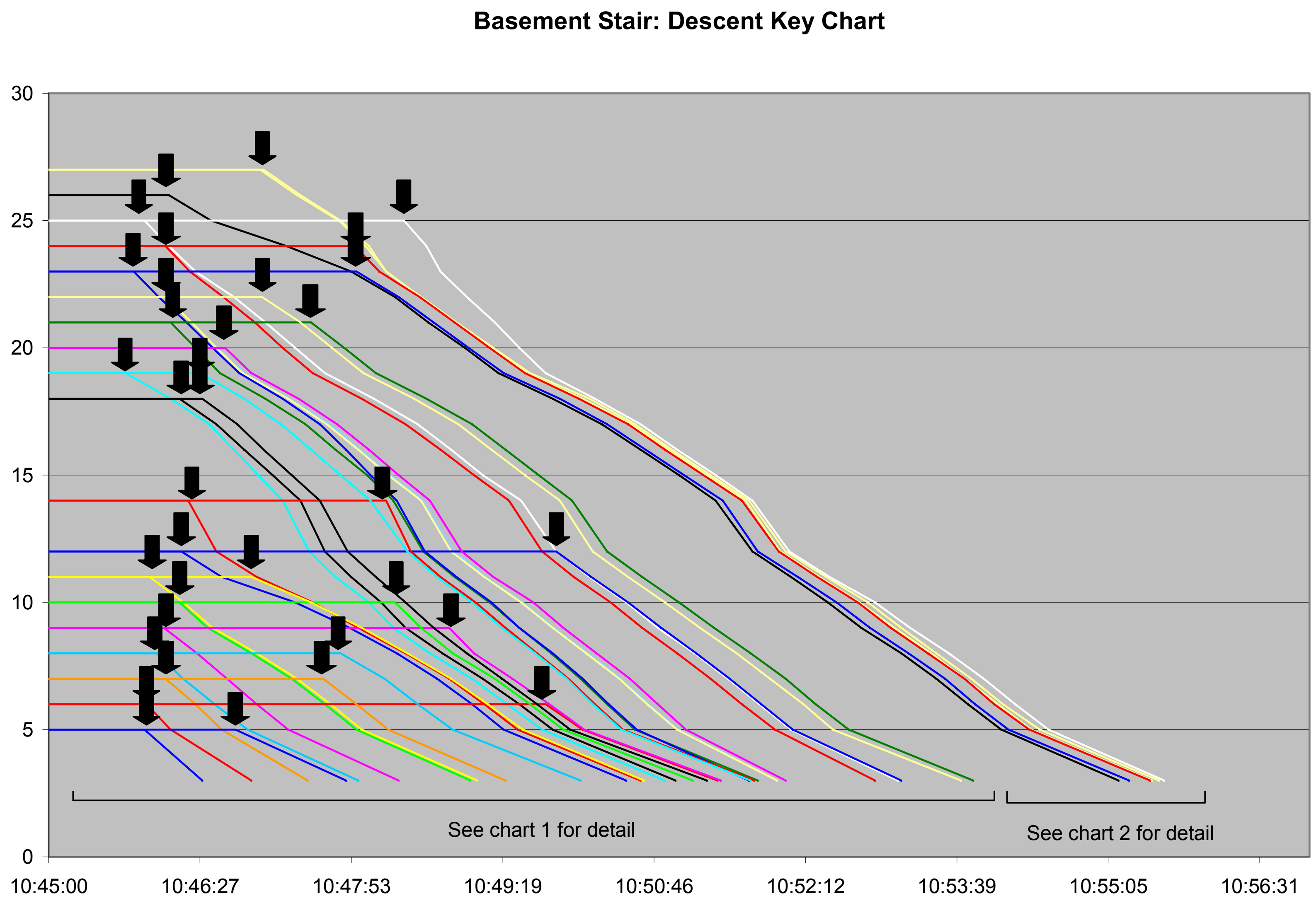
□	Yellow edged – overweight man carrying pram and toddler down the stairs stumbles at level 10 initially. Overtaken by others initially.	**NOTE:** The author was positioned one group behind the family. Father had problems negotiating the narrow 245-250mm wide treads. Pram obstructed his view. The descent speed of this group was 0.37m/sec which still resulted in an evacuation time of approximately six minutes.
◇	Pink edging - slim female less than 35 years no handrail with small child from level 11.Overtaken by others	
◇	Pink edging - overweight female less than 35 years from level 11 no handrail helping female above. Overtaken by others	
◇	Pink edging – slim female child no handrail and overtaken by others. Part of the above family group.	
Blue bar	Observer starting at level 17 – no one in front until level 9 where 2 in front and 0 on handrail changing to 4 in front and 2 on handrail.	

A7.6.4.2/M3 DESCENT CHARTS M3
Figure A56: M3 "DIRTY STAIR" = STAIR TWO



◻	Pink edged – slim male no handrail 35-59 years is overtaken by others.	See note on chart.

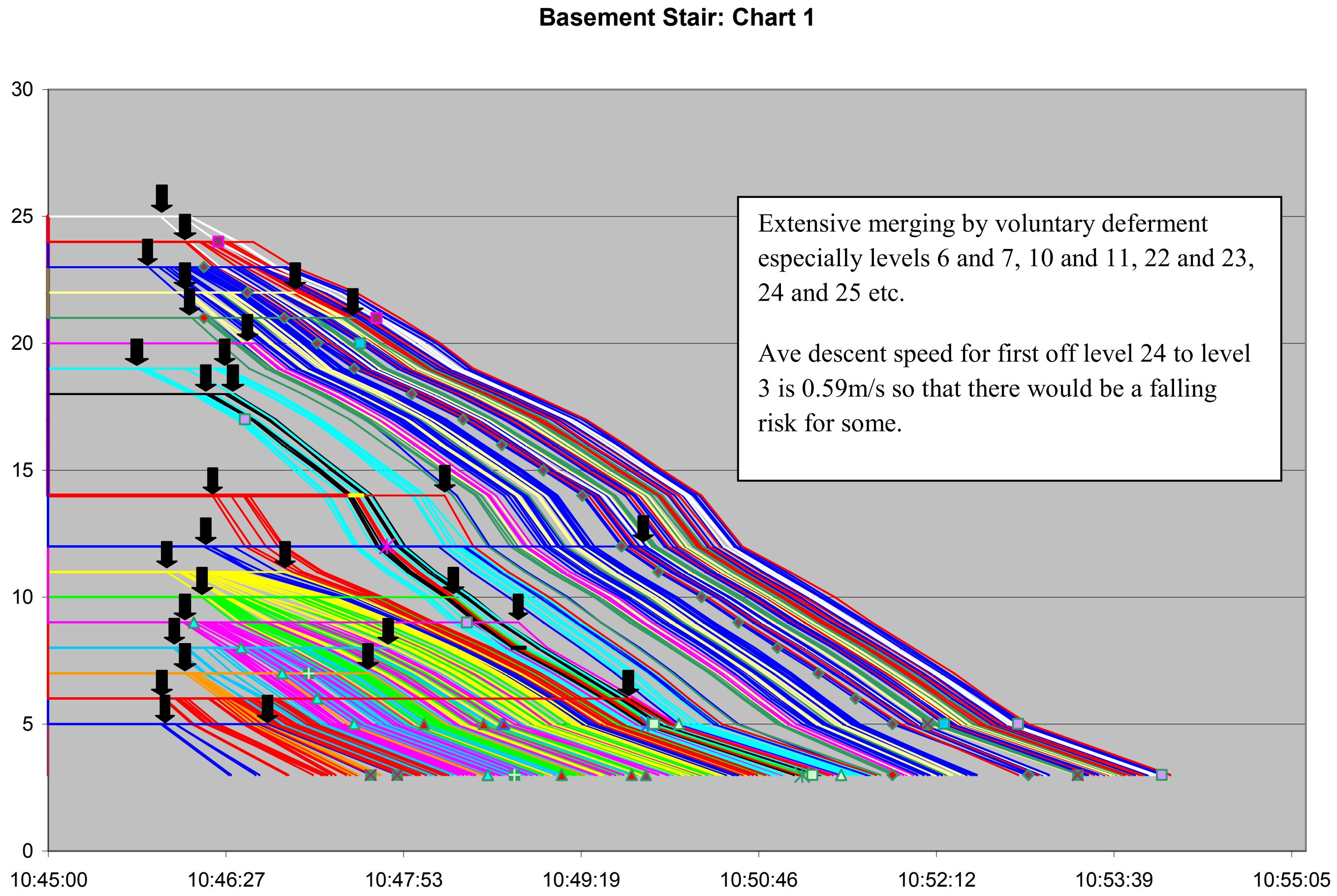
A7.6.4.2/M4 DESCENT CHARTS M4
Figure A57: M4 BASEMENT STAIR = STAIR ONE (KEY CHART)



*SEE CHARTS 1 AND 2 FOR DETAILED OBSERVATIONS

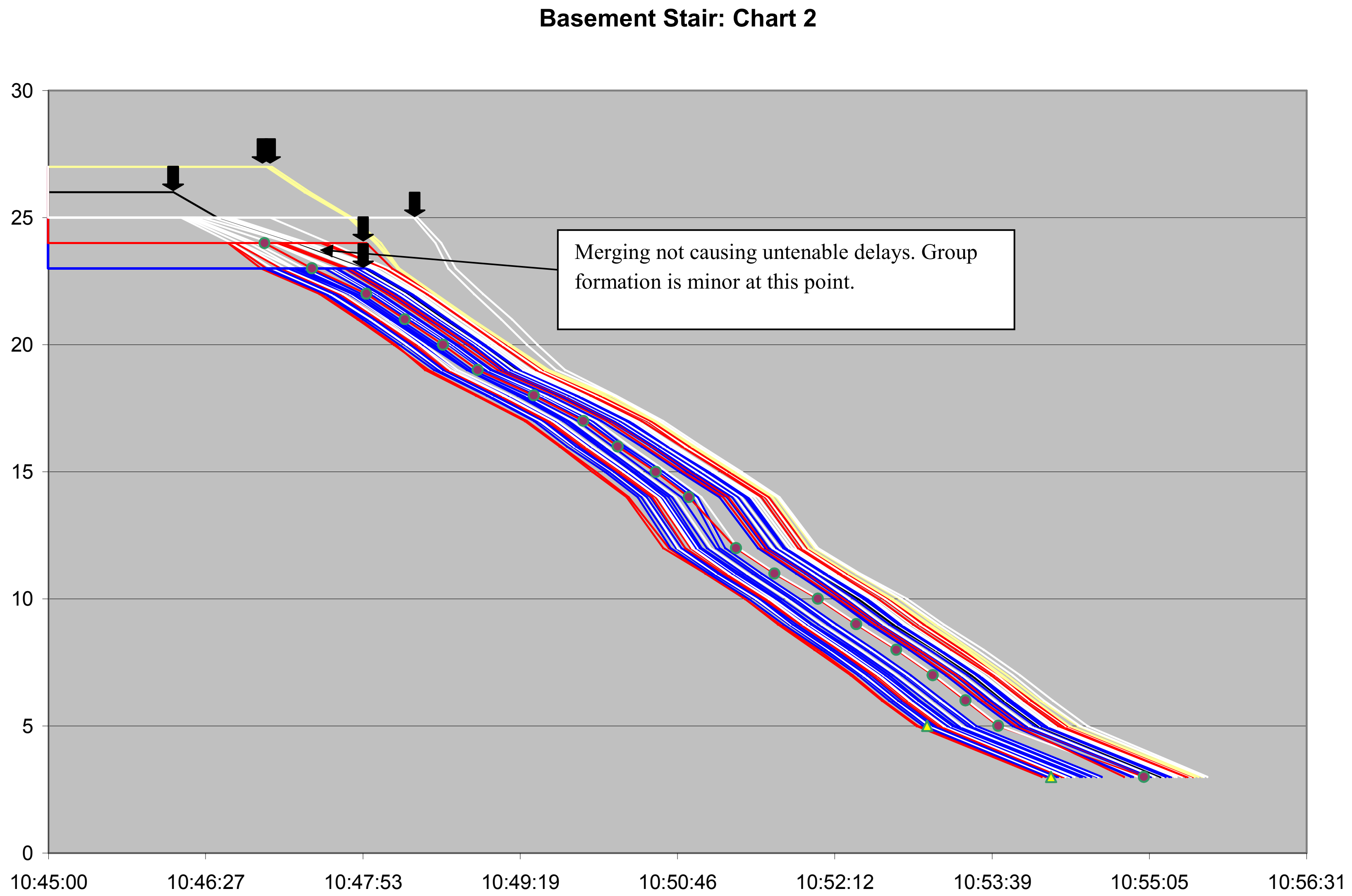
A7.6.4.2/M4 DESCENT CHARTS M4: STAIR ONE – CHART ONE

Figure A58: M4 STAIR ONE CHART ONE



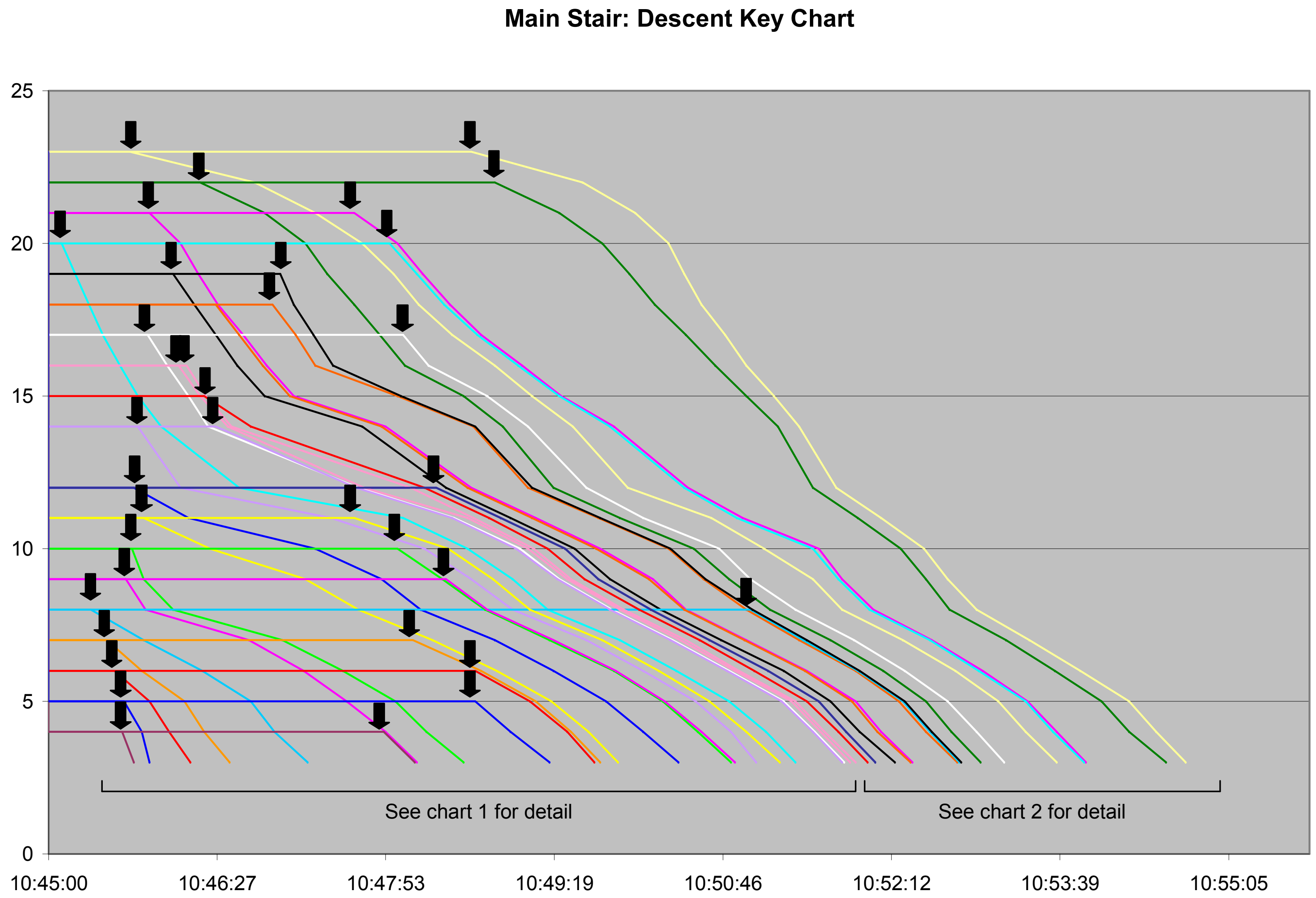
◆ (orange)	Green edging – from level 21 slim female less than 35 years no handrail but holding up others behind her.	
◆ (purple)	Green edging – from level 23 slim female less than 35 years using handrail holding up others behind her.	**NOTE:** 50% of those observed were female and of those 80% using the handrail. Descent speed is approx 0.59m/s.
■ (cyan)	Green edging – from level 21 overweight male using handrail and holding others up.	
■ (purple)	Pink edging – from level 24 slim male 35-59 years of age using the handrail and overtaken by others – slow mover with apparent functional limitations.	
■ (lilac)	Green edging – from level 19 slim male 35-59 years of age not on handrail and holding others up behind him.	
Yellow bar	Observer starting as yellow bar at level 14 with 4 in front and 1 on handrail to 10 in front and 4 on handrail at level 10.	
Purple cross	Slim females from levels 5 and 9 over 60 years using handrail and holding others up behind.	
Yellow cross	Overweight male from level 9 using handrail and significantly overtaken.	
▲ (red)	Blue edged - slim female from level 9 – 35-39 years of age with high heels and using handrail.	
▲ (purple)	Green edged – slim female from level 9 35-39 years using handrail and holding others up behind.	
□ (light green)	Green edged – overweight male 35 – 39 years using handrail and holding others up behind	

A7.6.4.2/M4 DESCENT CHARTS M4: STAIR ONE – CHART ONE
Figure A59: M4 STAIR ONE CHART TWO



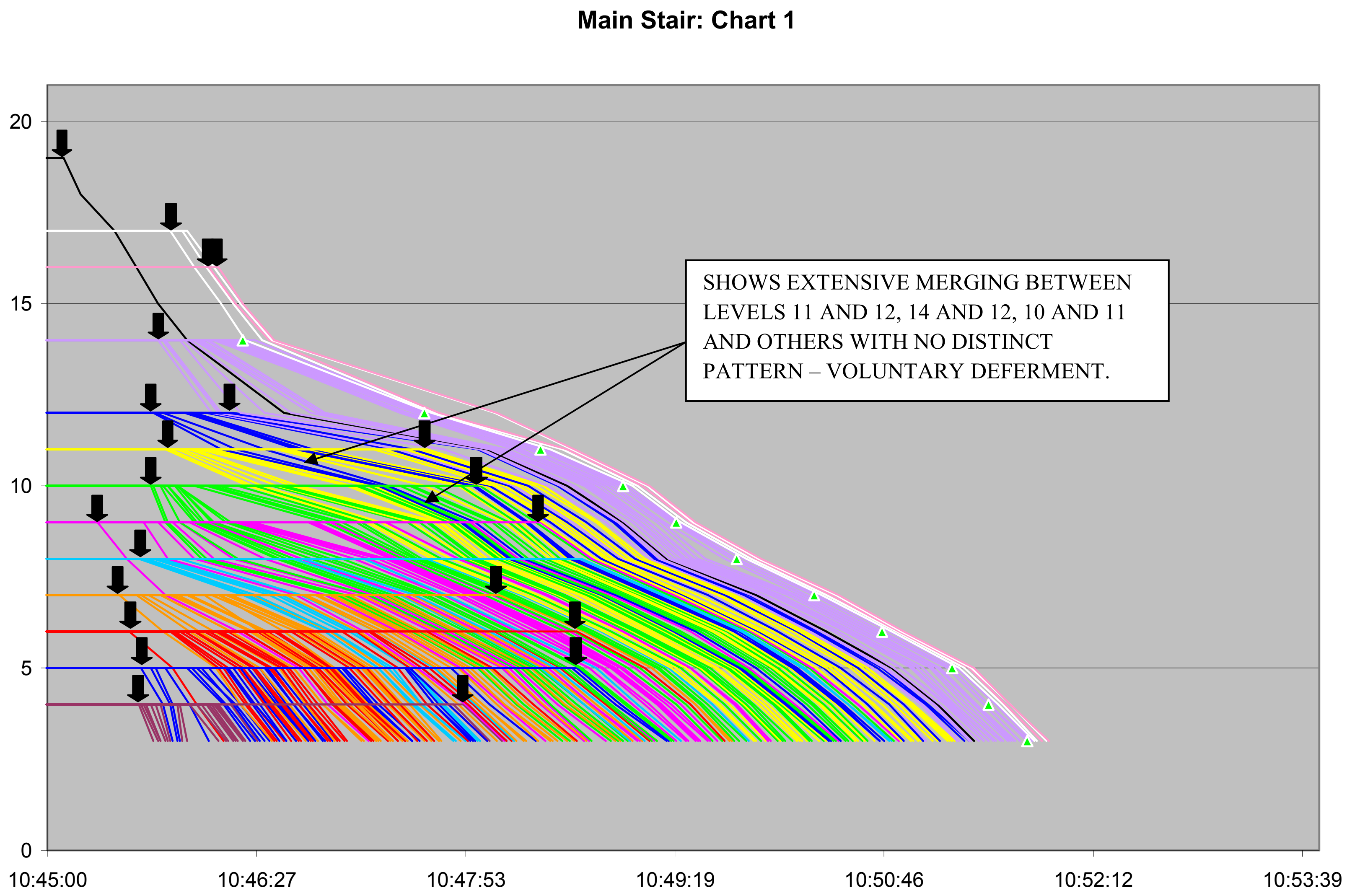
●	Green edging – slim male from level 24 less than 35 years using handrail and overtaken by others from level 23 – may have even rested. Also held up others behind him.	**NOTE:** Refer to Chart 1 for extent of merging and resultant delays.
△	Green edging – obese female 35-59 years of age from level 23 not using handrail but slow mover.	

A7.6.4.2/M4 DESCENT CHARTS M4: STAIR TWO– KEY CHART
Figure A60: M4 MAIN STAIR = STAIR TWO



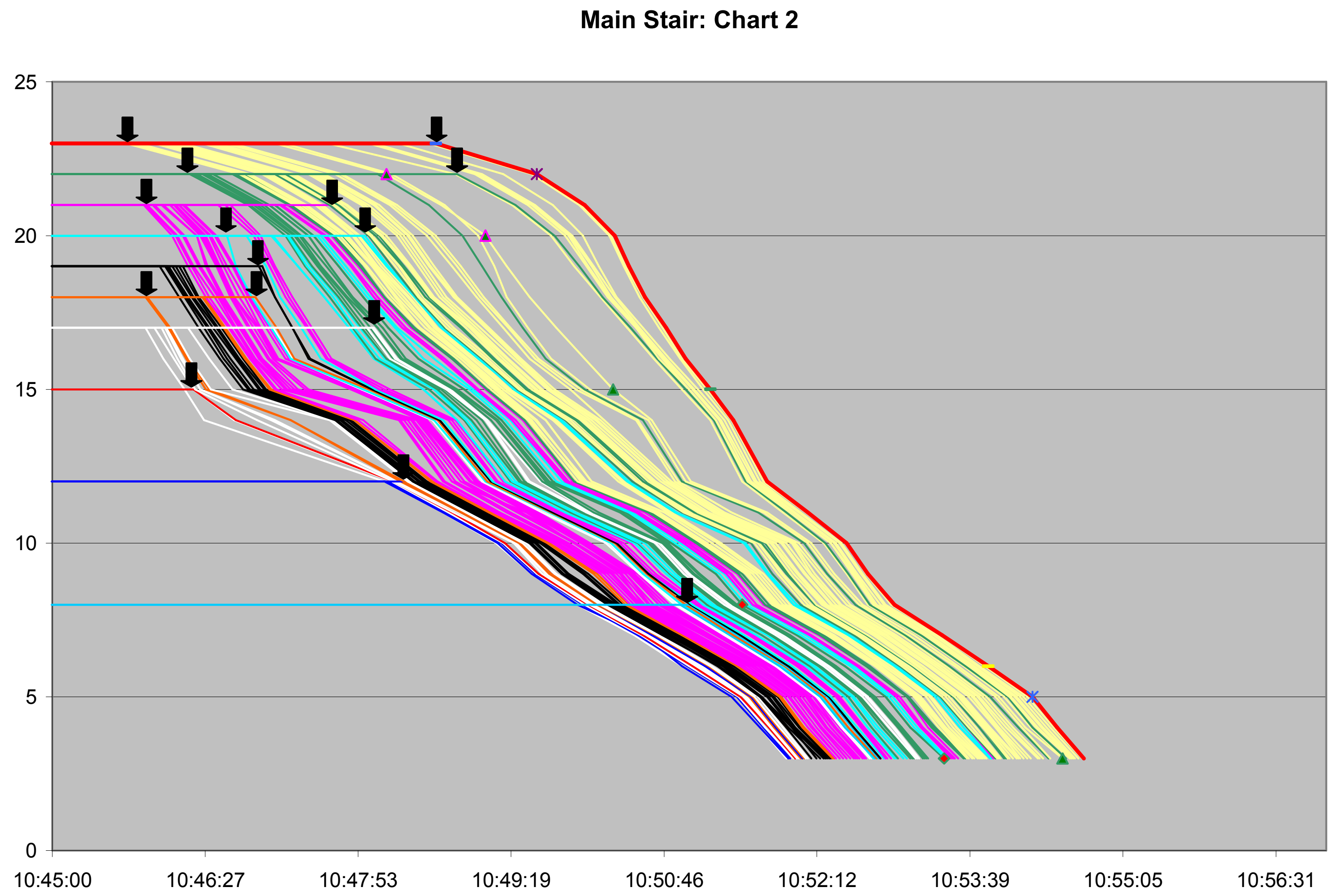
* SEE CHARTS 1 AND 2 FOR OBSERVER DETAIL

A7.6.4.2/M4 DESCENT CHARTS M4: STAIR TWO– CHART ONE
Figure A61: M4 STAIR TWO CHART ONE



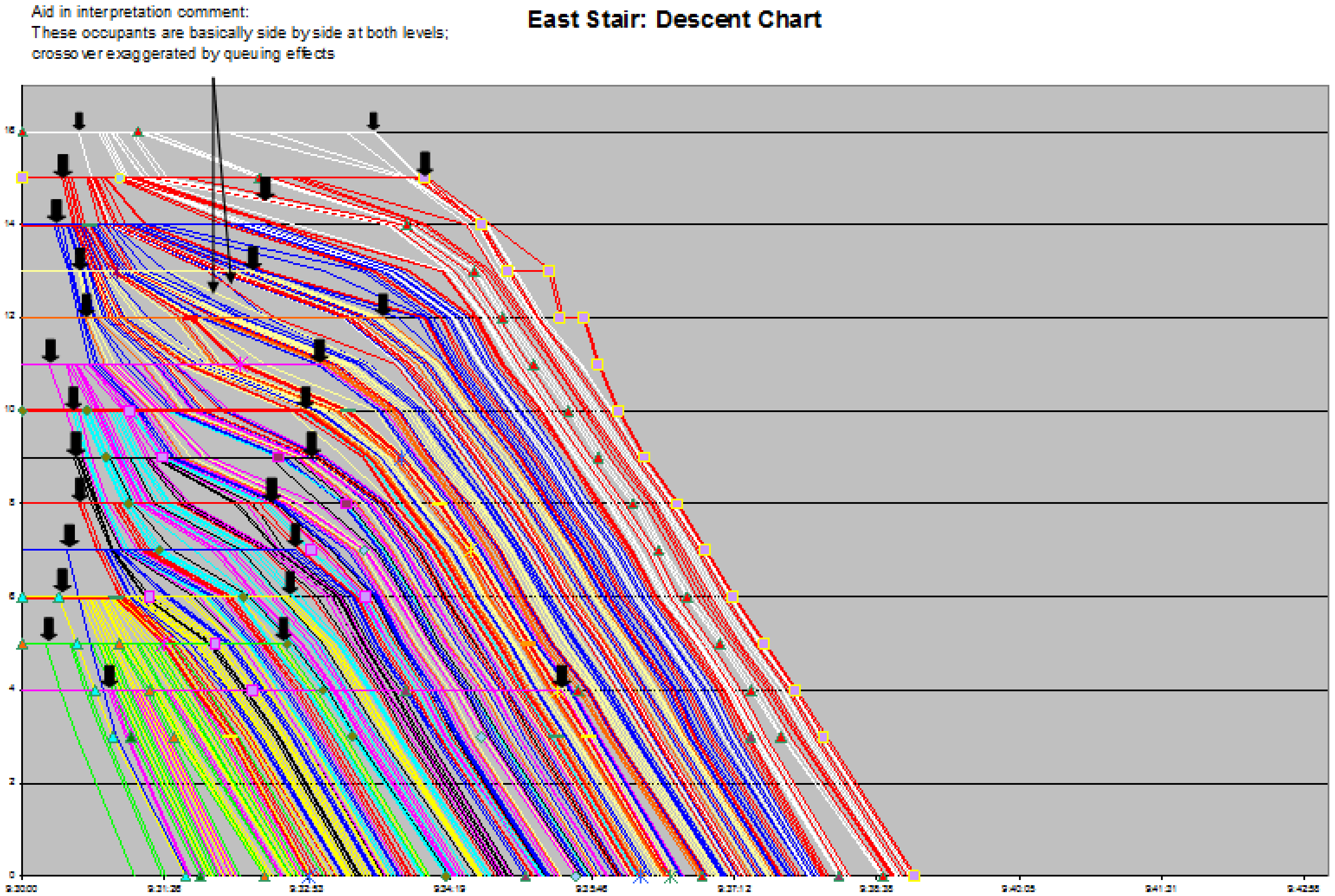
	White edged - from level 17 an overweight female 35-59 years of age with functional limitations assisted by occupants from level below. Interesting to note how group from level 14 deferred to her and she became part of their group for a while.	**NOTE:** Average descent speed of 0.39m/sec is within benchmark of Fuller Figure and Mature Age Focus Groups.

A7.6.4.2/M4   DESCENT CHARTS M4: STAIR TWO– CHART TWO
Figure A62: M4 STAIR TWO CHART TWO



		NOTE:
▲ (green triangle)	Pink edging – overweight female 35-59 years using handrail and being overtaken by a few people.	Only two females who were slow movers, one due to high heels and other because of unknown functional limitations.
▲ (green triangle)	Green edging – overweight female as above but this time holding people up behind her.	
◆ (red diamond)	Green edging – slim female under 35 years with high heels using handrail and holding up others behind.	
Yellow bar	4 occupants in front with 3 on handrail at level 4 increasing from 1 at level 23	

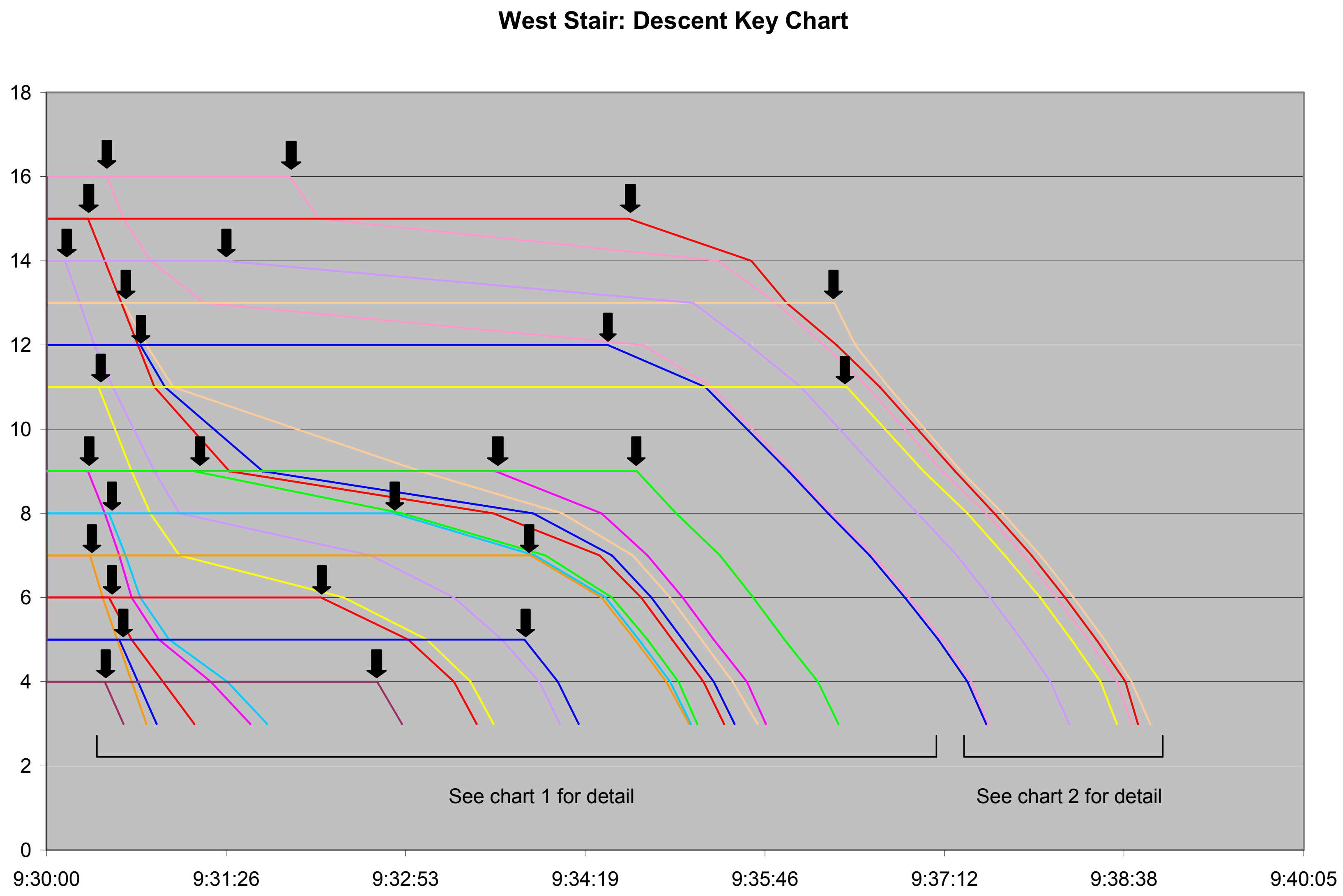
A7.6.4.2/M5 DESCENT CHARTS M5: STAIR ONE
Figure A63: M5 EAST STAIR = STAIR ONE



	Green edged – overweight 35-59 years female in sandals using handrail and holding others up behind her.
	Pink edged – slim male 35 -59 years not using handrail but slow mover and overtaken by others.
	Red observer bar starts on level 12 with 3 occupants in front and 1 on handrail increasing to 4 in front and 3 on handrail at level 6.
	Pink edged – slim male 35-59 years of age using handrail and overtaken by a few people.
	Green edged – obese female 35-59 years of age holding up others behind and using handrail.
	Green edged – overweight female 35-59 years of age using handrail and holding up others behind.
	Green edged – obese female 35-59 years of age using handrail and holding up others behind
	Green edged – slim female 35 -59 years of age using handrail and holding up others behind.
	Green edged – slim female 35-59 years of age using handrail, wearing high heels and holding up others behind.
	Observer from level 10 with 4 in front and two on handrail for entire journey.
	Green edging – slim female less than 35 years using handrail and holding up others.
	Yellow edging – slim male 35-59 years writing on paper and most likely an emergency services observer.

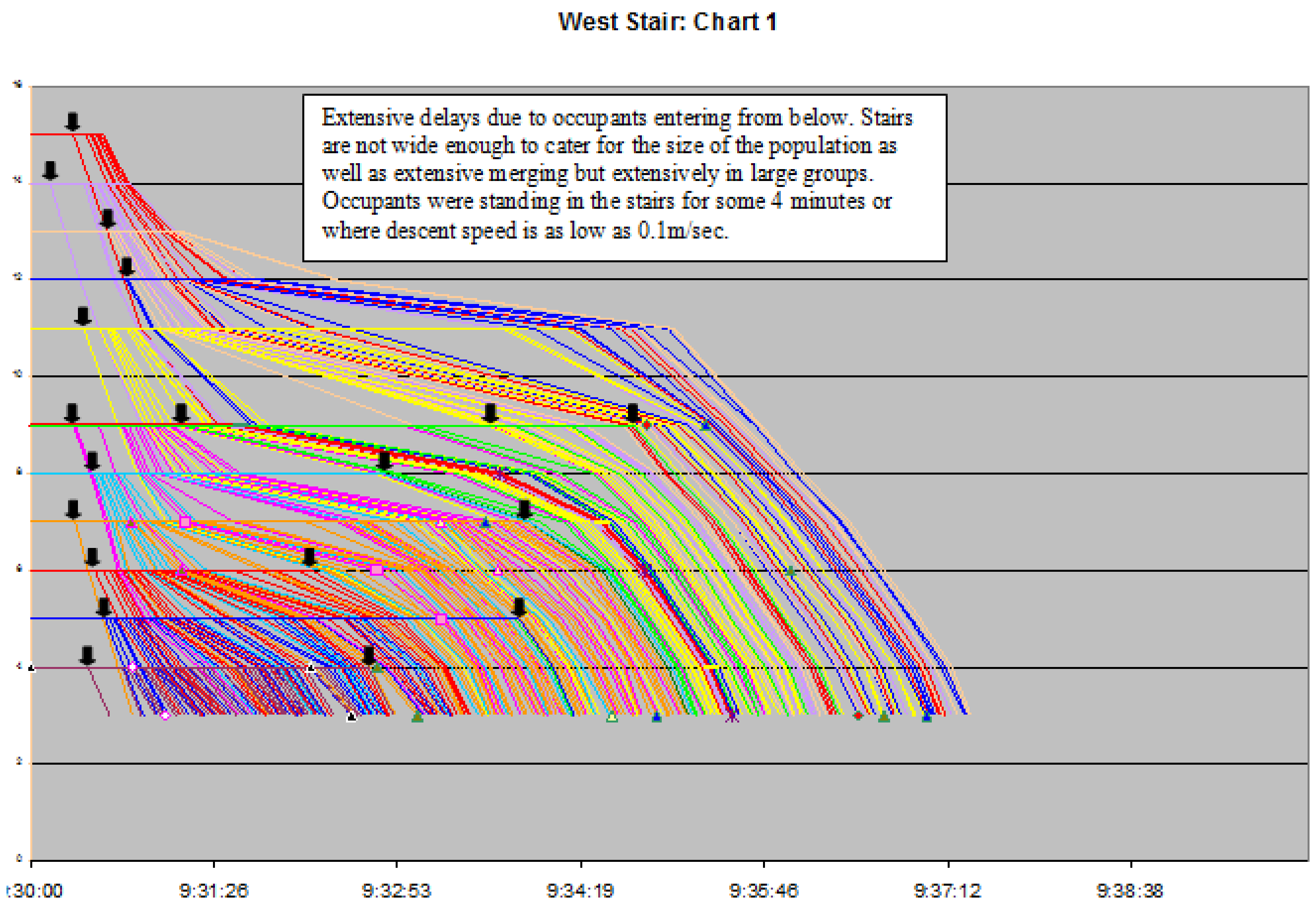
NOTE:
70% of those observed were female who were either being overtaken or holding others up. 86% of these females were using the handrail.

A7.6.4.2/M5 DESCENT CHARTS M5: STAIR TWO: KEY CHART
Figure A64: M5 WEST STAIR = STAIR TWO: KEY CHART



* SEE CHARTS 1 AND 2 FOR DETAILS OF OBSERVATIONS

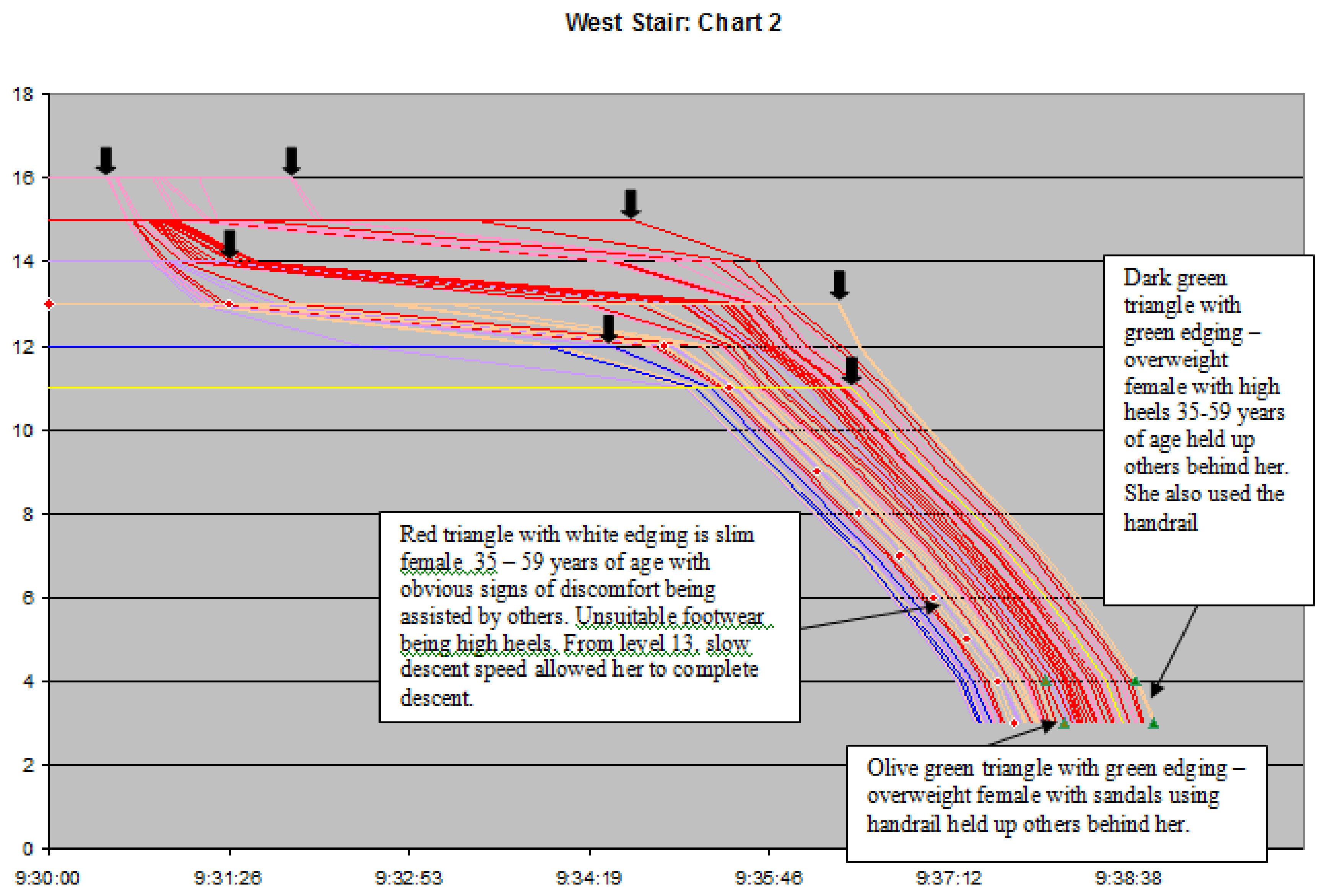
A7.6.4.2/M5 DESCENT CHARTS M5: STAIR TWO: CHART ONE
Figure A65: M5 WEST STAIR = STAIR 2 CHART ONE



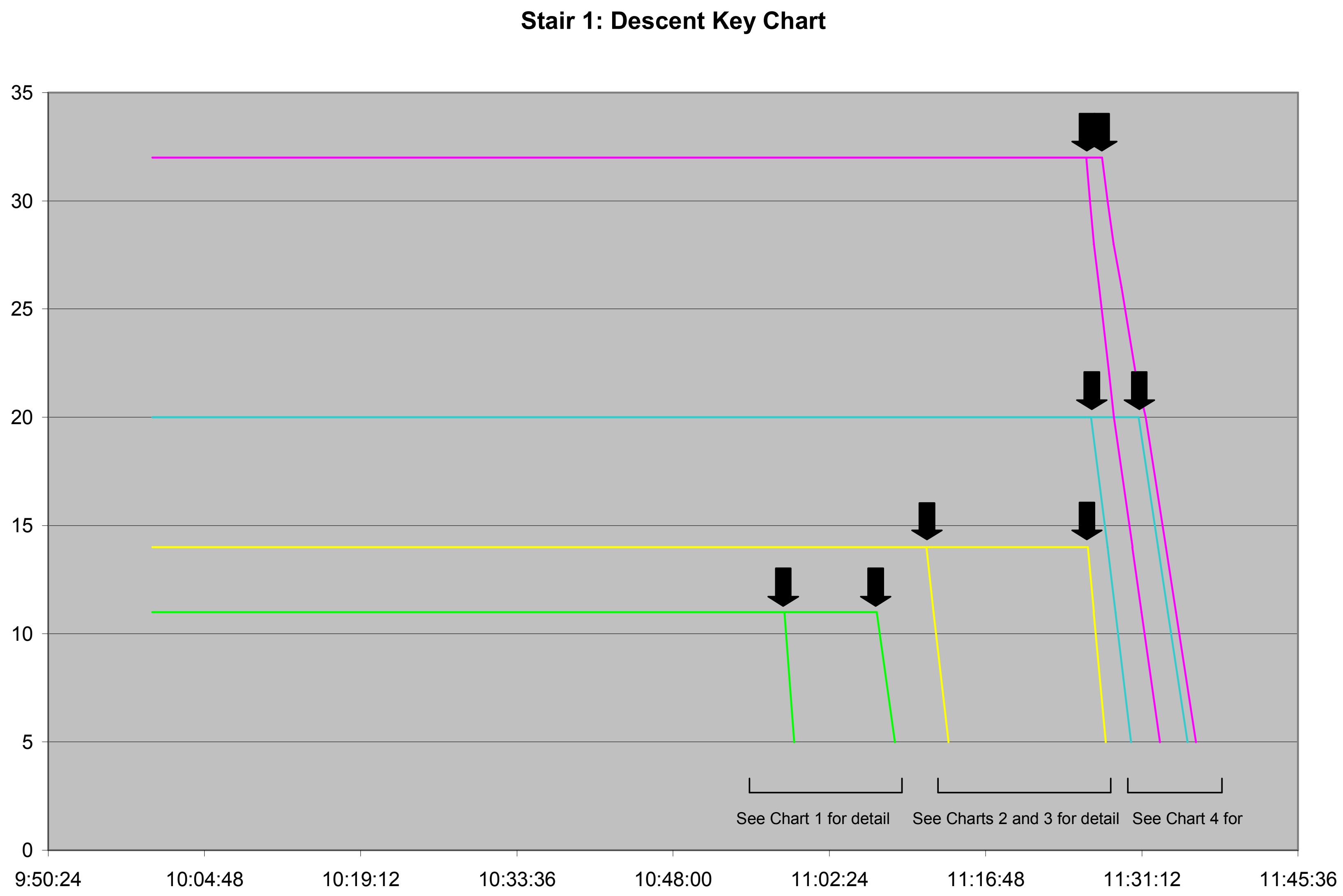
	Pink edging – slim 35-59 years female no handrail – was overtaken by others – slow mover.
	Pink edging – slim male 35 -59 years with sports shoes no handrail but was overtaken by others – slow mover.
	Pink edging – slim female less than 35 years no handrail and was overtaken by others – slow mover.
	White edging – vision impaired female 35 - 59 years assisted by others and with other apparent functional limitations – using handrail.
	Green edging – overweight female with sandals 35-59 held up others behind her
	Green edging – two occupants overweight females between 35-59 years with high heels using handrail and held up others behind her.
	Green edging – slim female less than 35 years with high heels using handrail and held up others behind her
x	Observer bar from level 9 with average of 3-4 occupants in front with only one on the handrail.

NOTE: 84% of those observed were female, one of which was vision impaired, four were overweight. They were all slow movers and two of the overweight females wore high heels. Either held others up or were overtaken. Extensive queuing in the stairs which triangulates well with 75% return from survey "crowded and moving slowly".

A7.6.4.2/M5 DESCENT CHARTS M5: STAIR TWO: CHART TWO
Figure A66: M5 WEST STAIR = STAIR 2 CHART TWO

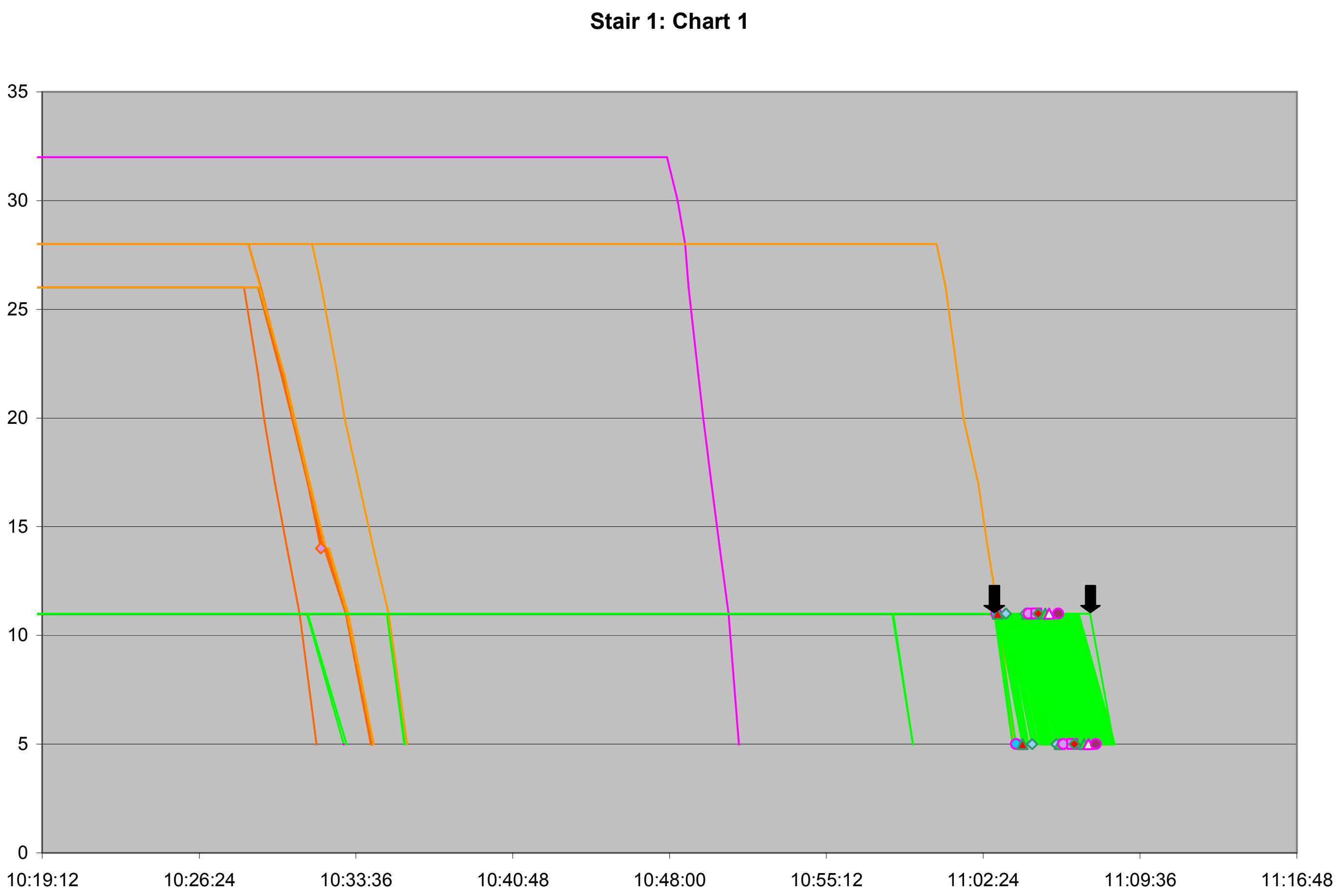


A7.6.4.2/M6 DESCENT CHARTS M6: STAIR ONE: KEY CHART
Figure A67: M6 STAIR ONE KEY DESCENT CHART



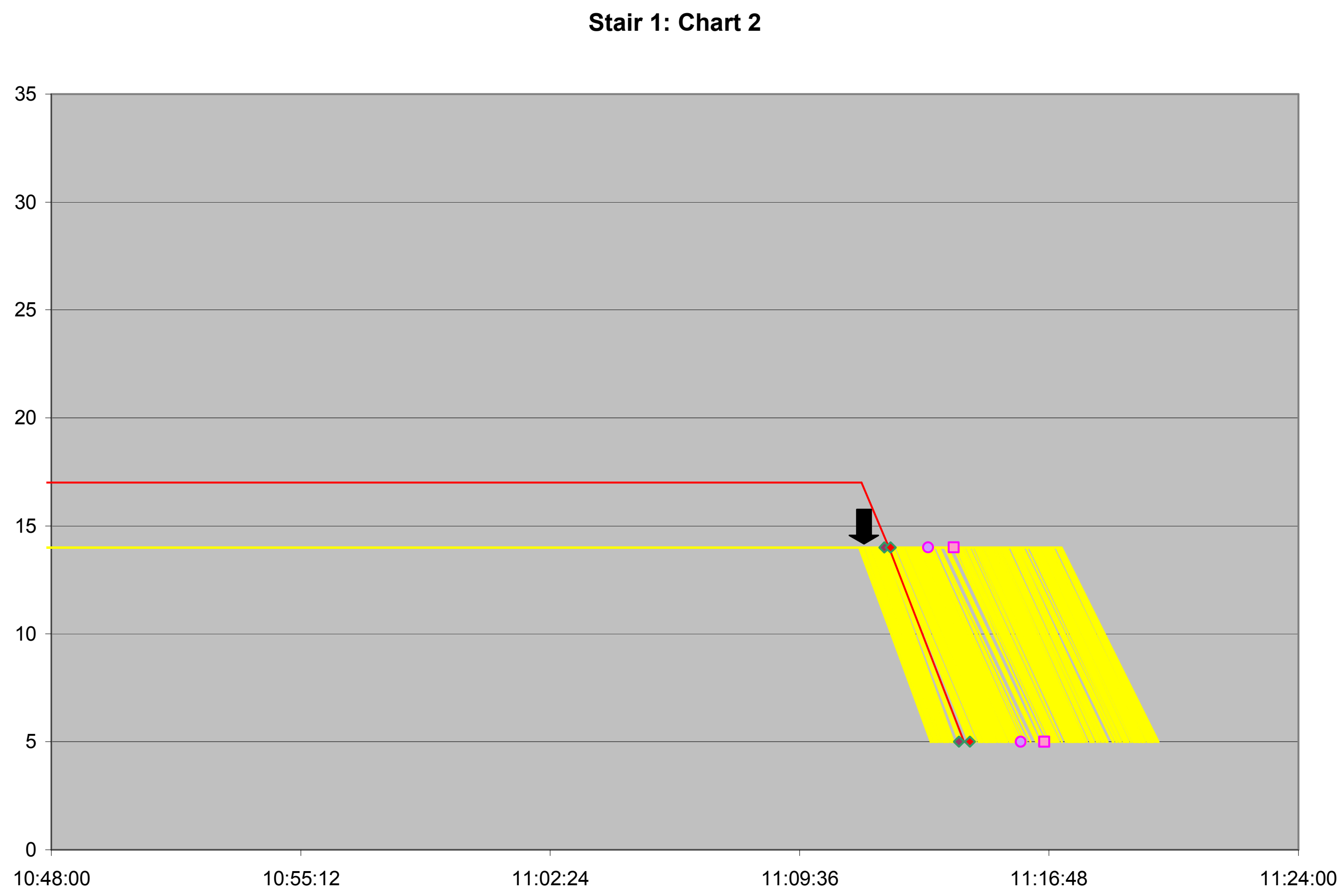
SEE DETAILED CHARTS 1-4 FOR DETAILED OBSERVATIONS

A7.6.4.2/M6   DESCENT CHARTS M6: STAIR ONE: CHART ONE
Figure A68: M6 STAIR ONE DESCENT CHART ONE



Lilac triangle	Pink edged – slim female 35-59 years overtaken by a few people from level 26.	**NOTE**: 50% of those observed were females. High heel shoes featured again and group cohesion appears to account for slow descent speed.
Blue circle	Pink edged – slim male less than 35 years using handrail from level 11 overtaken by a few people	
Red triangle	Green edged – slim female 35-59 years using handrail from level 11 held others up behind them.	
Light green diamond	Green edging overweight not using handrail held up others behind – level 11	
Lilac circle	Pink edging – slim male less than 35 years light use of handrail was overtaken by a few people.	
Red diamond	Green edging – slim female less than 35 years with high heels held up others behind and used the handrail.	
Yellow triangle	Pink edging – obese female in sandals using handrail 35 -59 years of age overtaken by a few people.	
Plum circle	Pink edging slim male less than 35 years using handrail overtaken by a few people	

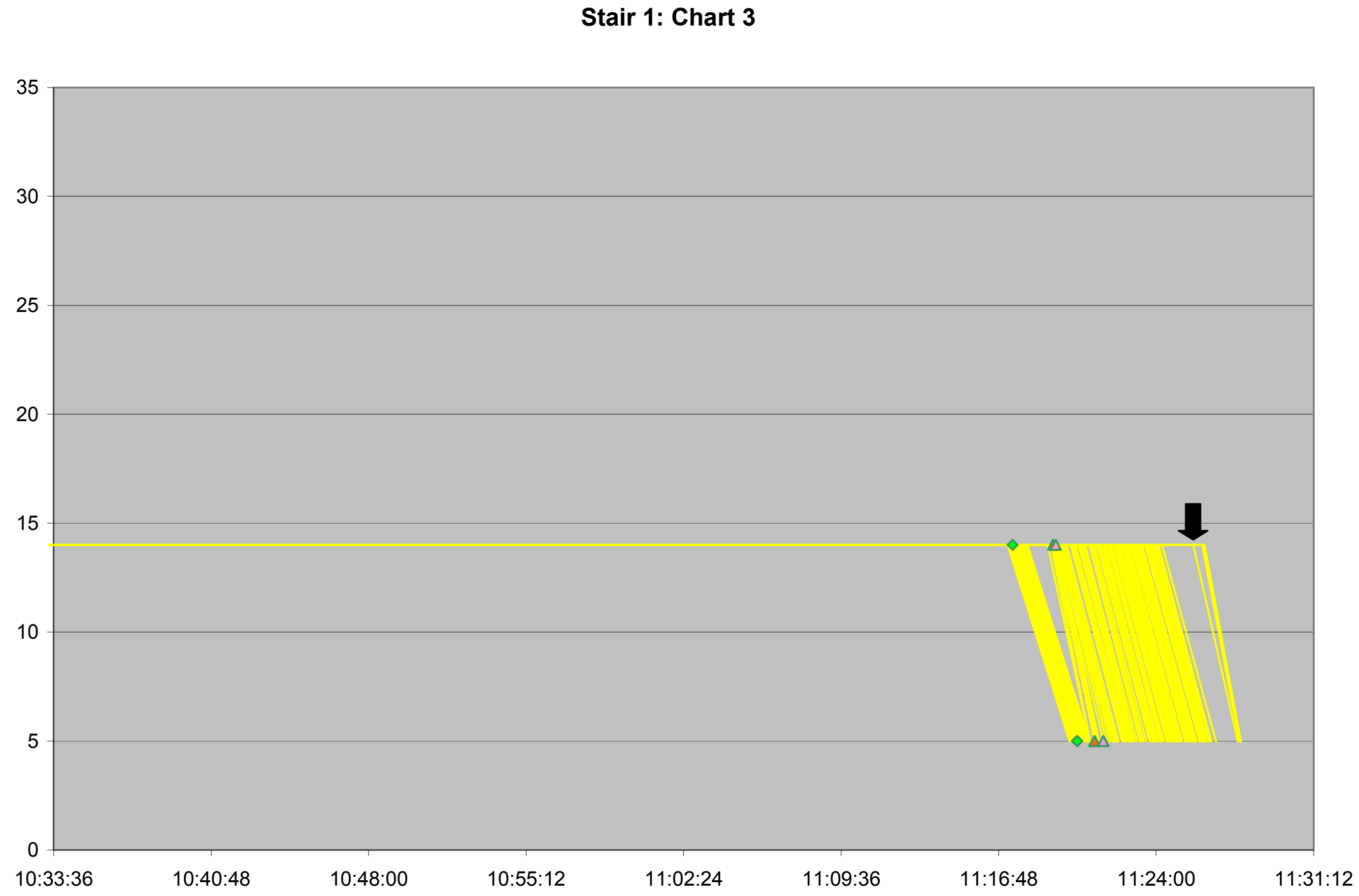
A7.6.4.2/M6 DESCENT CHARTS M6: STAIR ONE: CHART TWO
Figure A69:M6 STAIR ONE DESCENT CHART TWO



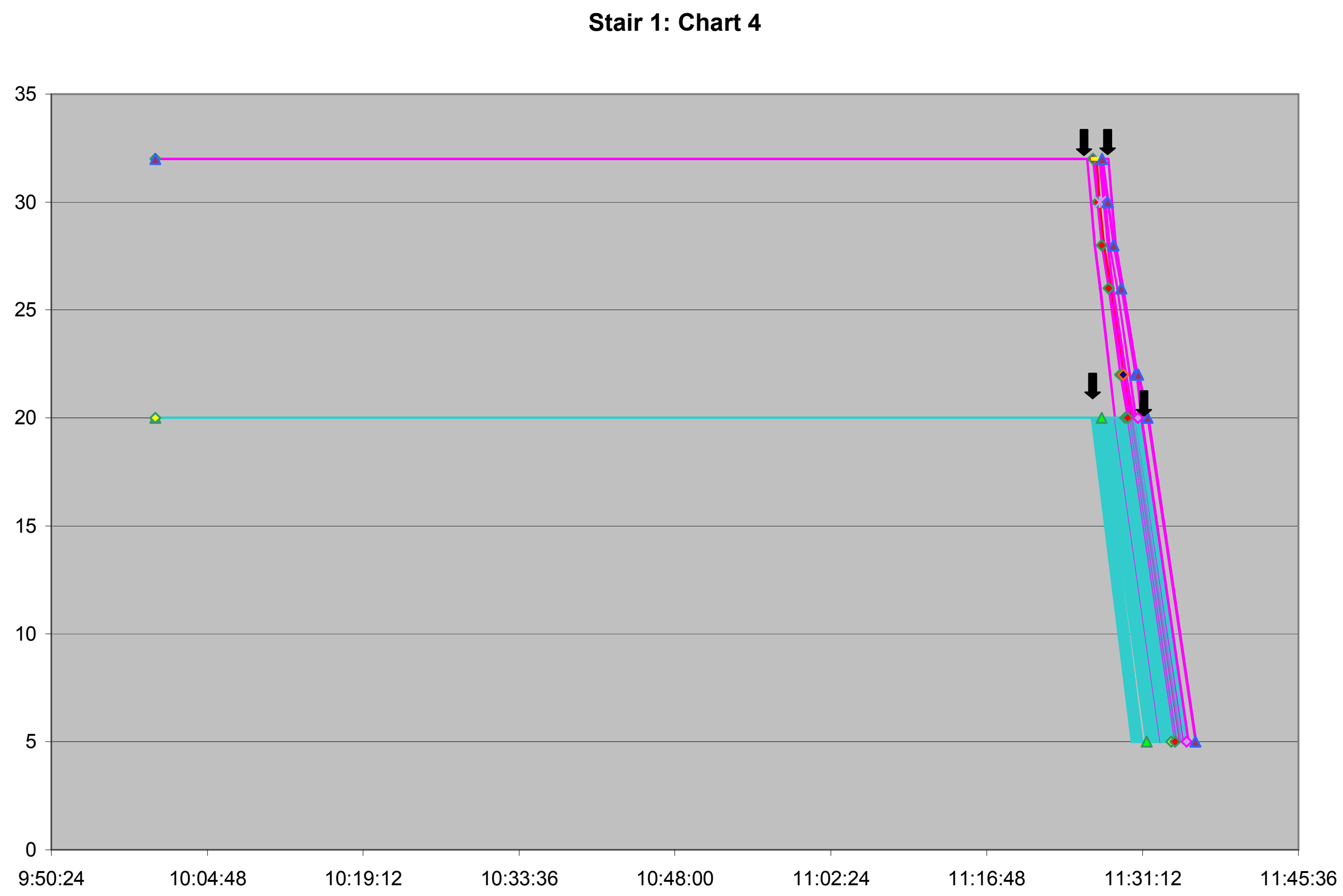
◆ (red diamond)	Green edging – slim female less than 35 years with high heels held up others behind her and used handrail.	**NOTE:** 50% female observed one of which wore high heels and held up others. All four appear to have been a group of sorts. All from Level 14
◆ (purple diamond)	Green edging slim female less than 35 years accompanying the above female and holding up others behind – did not use handrail.	
● (purple circle)	Pink edging – slim male less than 35 years light use of handrail overtaken by a few people.	
■ (pink square)	Pink edging – slim male less than 35 years no handrail and overtaken by a few people	

A7.6.4.2/M6 DESCENT CHARTS M6: STAIR ONE: CHART THREE
Figure A70: M6 STAIR ONE DESCENT CHART THREE

◆	Green edging – overweight female less than 35 years using handrail and held up others behind	
▲	Green edging – obese female 35-59 years using handrail held up others behind her	
▲	Blue edging – slim female 35-59 years of age with sports shoes not using handrail but was significantly overtaken.	

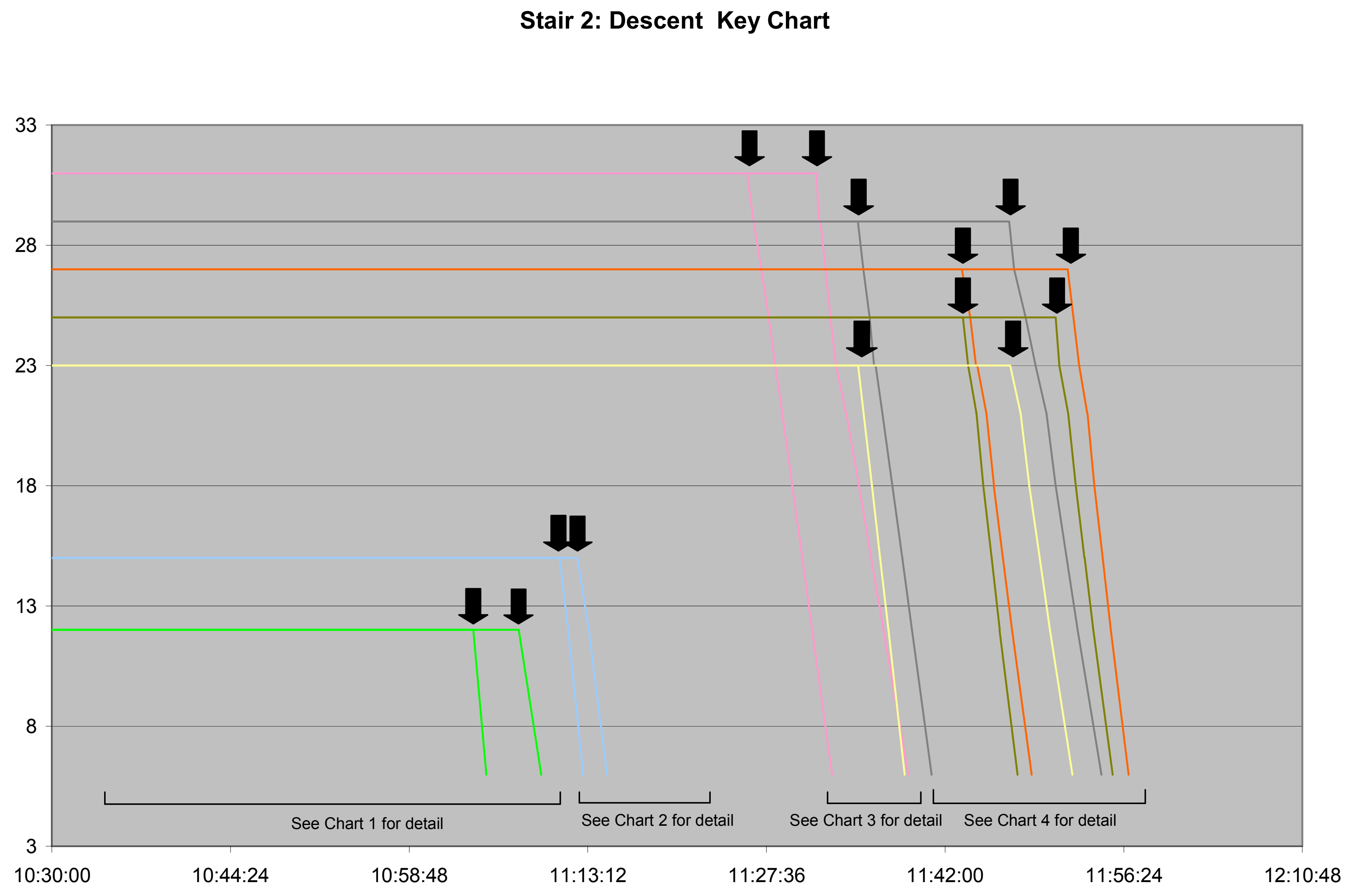


A7.6.4.2/M6 DESCENT CHARTS M6: STAIR ONE: CHART FOUR
Figure A71: M6 STAIR ONE DESCENT CHART FOUR



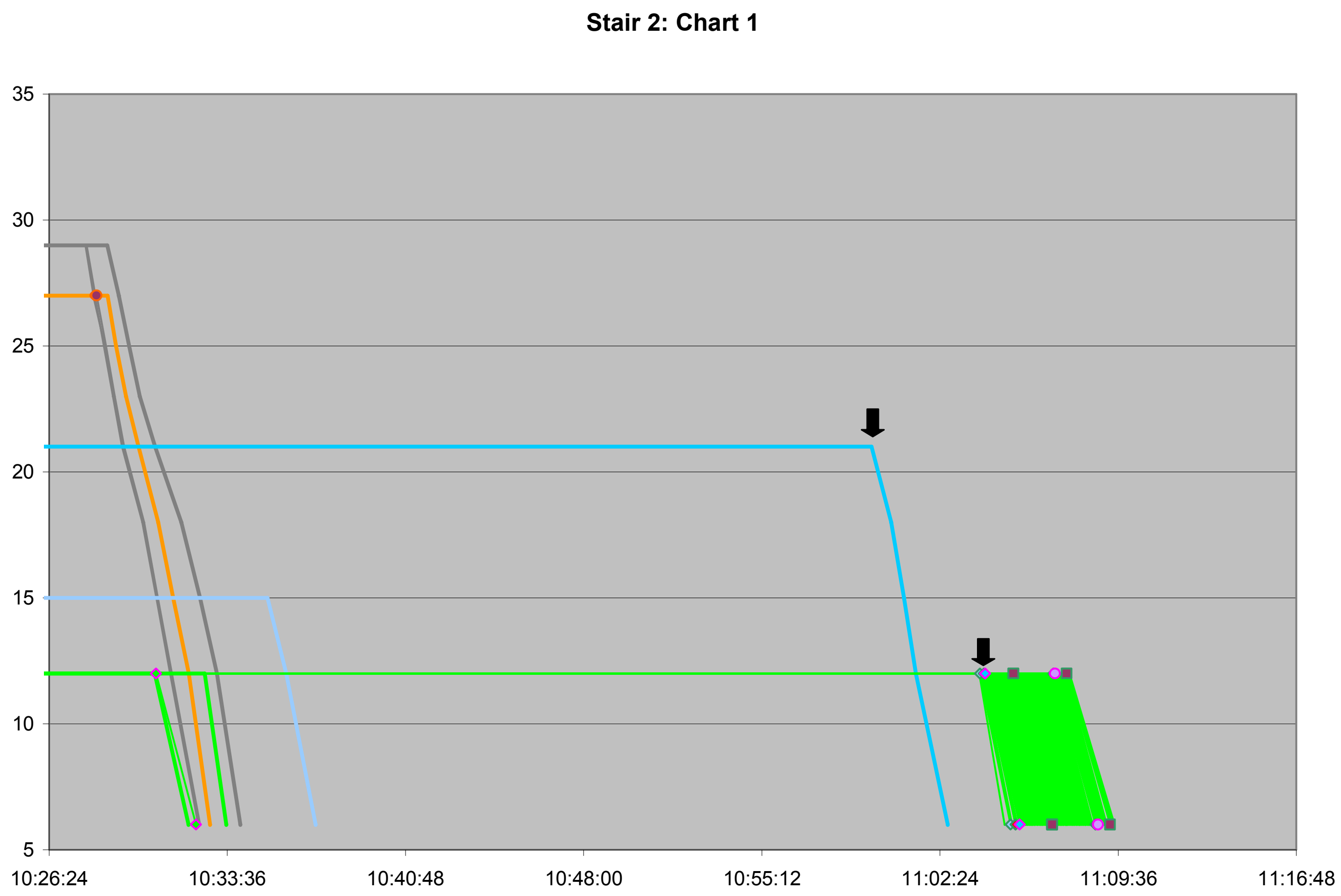
◇ (yellow diamond)	Green edging obese female less than 35 years using handrail held up others behind her	**NOTE:** Observer comments from level 32 imply full flight of occupants with all of them holding the handrail. This triangulates with video observations.
△ (purple triangle)	Blue edging – slim female 35-59 years using handrail significantly overtaken by others – apparent functional limitations	
△ (green triangle)	Green edged – overweight female 35-59 years of age held others up behind her.	
◆ (red diamond)	Green edged – slim female under 35 years with high heels held up others behind her.	
◇ (pink diamond)	Pink edged – slim female with high heels under 35 years overtaken by a few people	
◆ (navy diamond)	Orange edging – overweight female in sports shoes using the handrail rested on a landing	

A7.6.4.2/M6 DESCENT CHARTS M6: STAIR TWO: KEY CHART
Figure A72: M6 STAIR TWO DESCENT KEY CHART



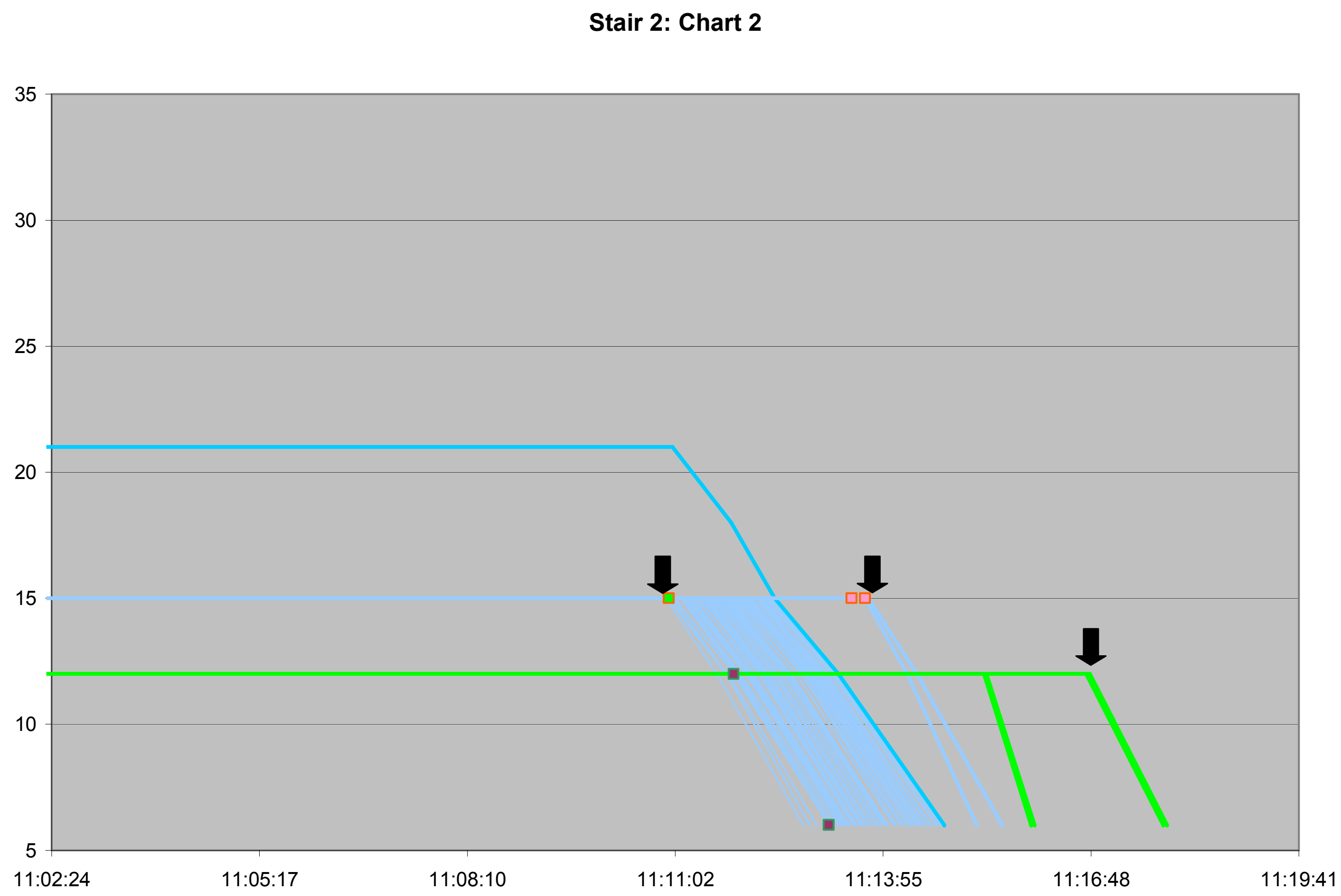
SEE CHARTS 1-4 FOR DETAILED OCCUPANT OBSERVATIONS

A7.6.4.2/M6 DESCENT CHARTS M6: STAIR TWO: CHART ONE
Figure A73 M6 STAIR TWO DESCENT CHART ONE



	Orange edged – slim male less than 35 years rested on landing and used handrail	NOTE: 43% of those observed were female. 43% of these occupants were overtaken apparently having decided to go at their own pace.
	Pink edged – overweight female less than 35 years using handrail overtaken by others	
	Green edged – overweight female less than 35 years not using handrail held up others in a small group of slow movers.	
	Pink edged – slim female less than 35 years using handrail overtaken by a few people	
	Green edged – slim 35 -59 year old male using handrail held up a few people	
	Pink edged – slim male less than 35 years light use of handrail and overtaken by a few people	

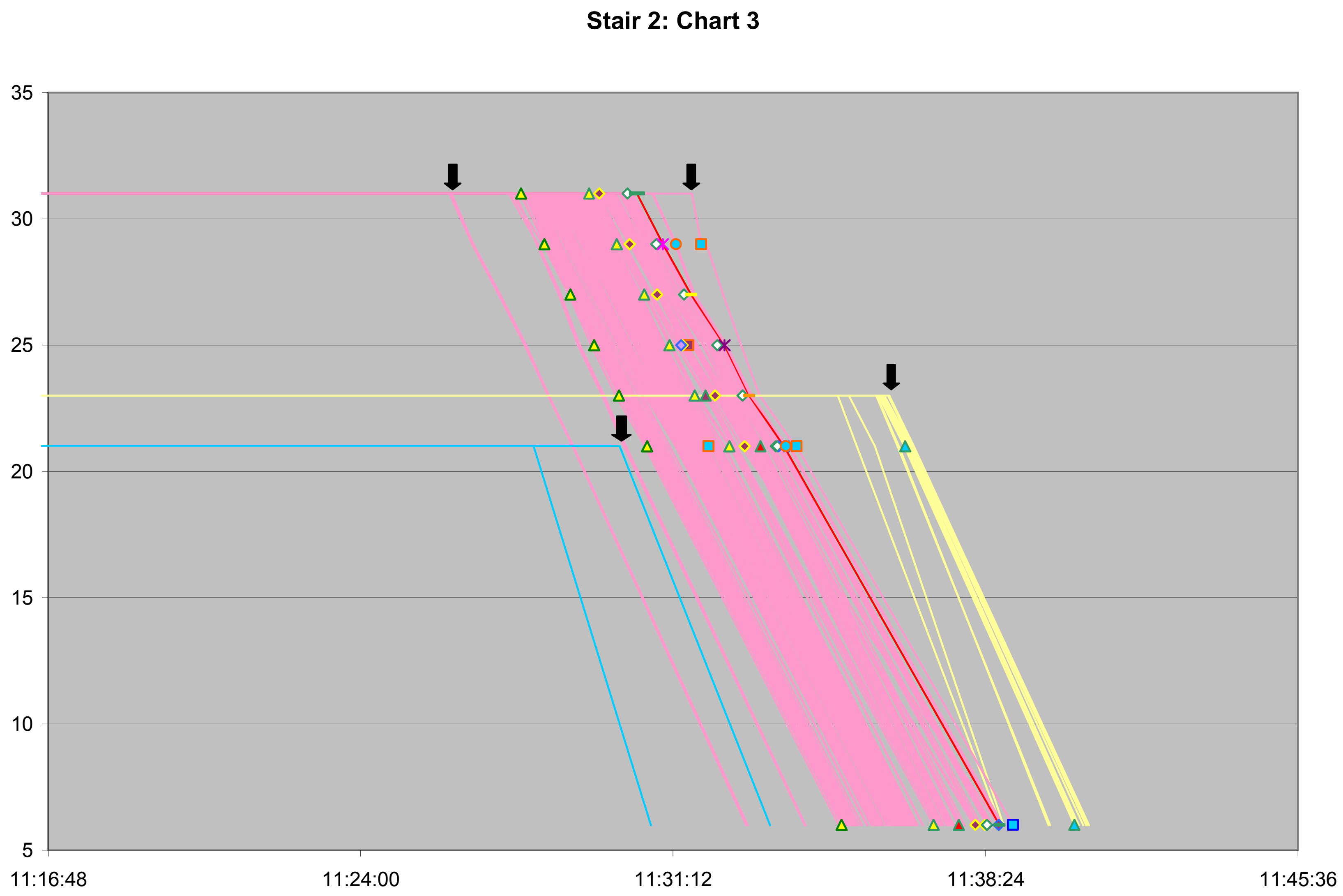
A7.6.4.2/M6 DESCENT CHARTS M6: STAIR TWO: CHART TWO
Figure A74: M6 STAIR TWO DESCENT CHART TWO

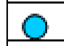
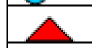
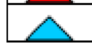


■	Orange edged – overweight 35-59 year old male using the handrail waits on landing of level 15.	**NOTE**: All males observed. Reasons for resting behaviour were inconclusive. No observer coverage.
■	Green edged – slim 35-59 year old male using the handrail held others up and he was first in a group from level 15 appears to have some functional limitation	
■	Orange edged – slim male 35-59 years not using handrail waits on landing on level 15.	

A7.6.4.2/M6 DESCENT CHARTS M6: STAIR TWO: CHART THREE

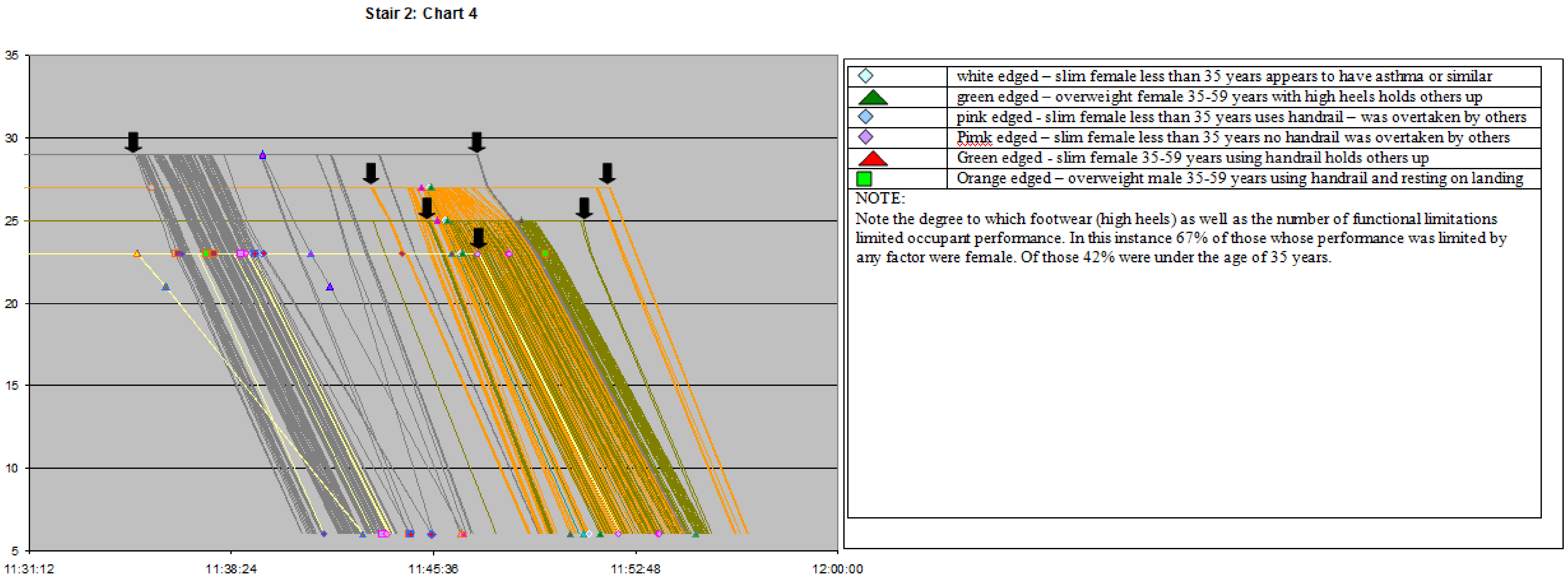
Figure A75: M6 STAIR TWO DESCENT CHART THREE



	Green edged - 35-39 year old obese female held up others	NOTE: 72% of those observed were female of which 40% were under the age of 35 years. Some of the problems were again footwear. Quite a few rested due to some limitation and were significantly overtaken. ***Observer comments*** in coloured bars commencing level 31: commences with 4 persons in front decreasing to 3 and with 1 using the handrail to 3 using the handrail. Group also decreased to 3 all of whom were using the handrail.
	Yellow edged – slim female under 35 years using handrail being assisted by female companion has obvious functional limitations	
	Green edged - slim female under 35 years with sports shoes held others up	
	Orange edged at start and blue edged at level 5– overweight 35 – 39 years old male using handrail and who rested and was significantly overtaken on each flight	
	Orange edged - slim male less than 35 years using handrail – also rested	
	Green edged - slim female 35 -59 years in high heel shoes held others up	
	Green edged – obese female 35-59 years using handrail held people up	

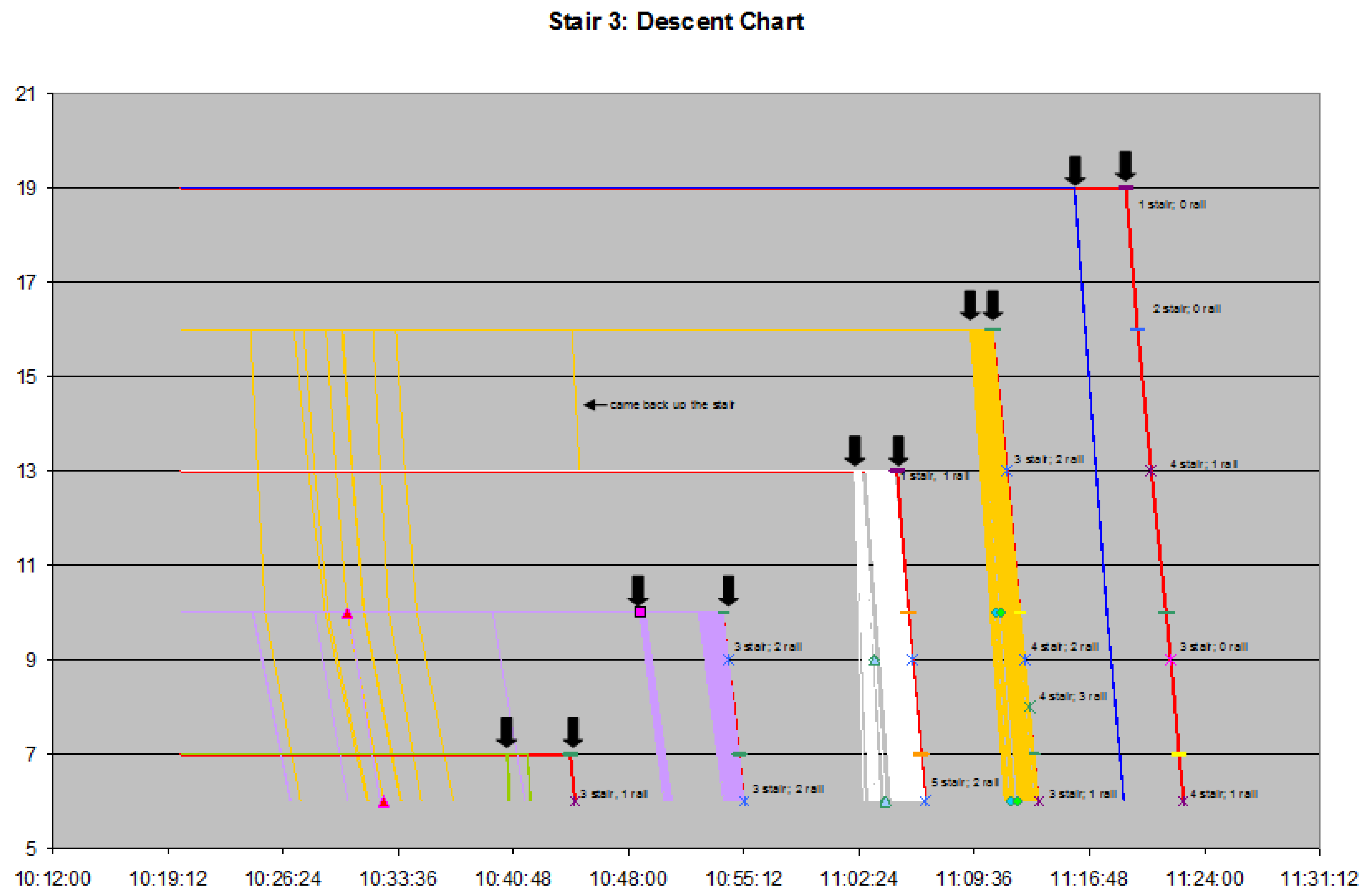
A7.6.4.2/M6 DESCENT CHARTS M6: STAIR TWO: CHART FOUR

Figure A76: M6 STAIR TWO DESCENT CHART FOUR



	Overweight female 35-59 years no handrail – overtaken by many others and rested at some point
	Slim male less than 35 years he rested for a while and waits for overweight male shown below
	Slim male 35 – 59 years rests on floor uses handrail
	Slim female less than 35 years using handrail – significantly overtaken by others
	Overweight male 35 – 59 years using the handrail – overtaken by a few people
	Slim male 35 -59 years no handrail is overtaken by a few people
	Slim female less than 35 years overtaken by a few people
+	Male older than 60 years was significantly overtaken by others
	Slim female less than 35 years in high heels, using handrail overtaken by others
	Slim female 35-59 years in high heels using handrail overtaken by others
	Slim female less than 35 years rests on landing (orange edging) – from level 27.
	Slim female 35-59 years uses handrail and was overtaken by a few people (pink edged)

A7.6.4.2/M6 DESCENT CHARTS M6: STAIR THREE
Figure A77: M6 STAIR THREE DESCENT CHART



Symbol	Description
Pink triangle	Slim female 35-59 years , sports shoes, handrail held up others behind.
Green X	All observer comments shown on chart
Pink square	Slim male 35-59 years holding handrail and holding up others behind
Blue triangle	Green edged – obese female 35-59 years held others up no handrail
Blue square	Green edged - overweight male helping female no handrail
Green diamond	Overweight female less than 35 years using handrail – holds up others
Blue diamond	Slim female less than 35 years using handrail – holds up others

NOTE:
67% were female and of those 60% hold the handrail.
No merging as evacuation was sequential in designated stairs.

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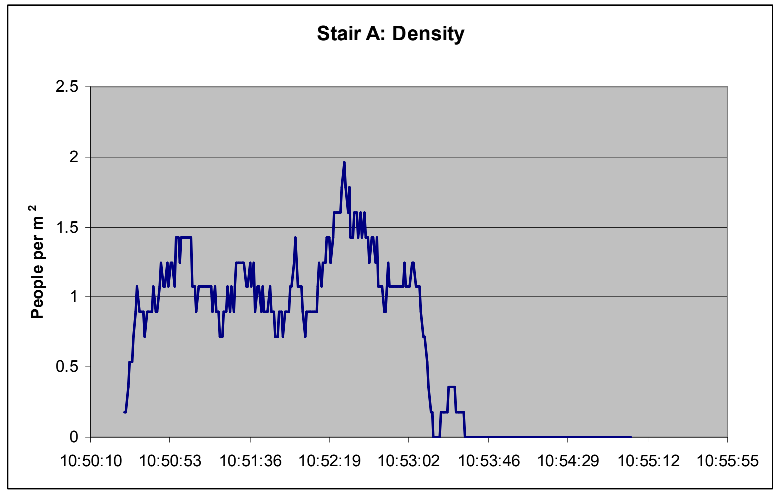
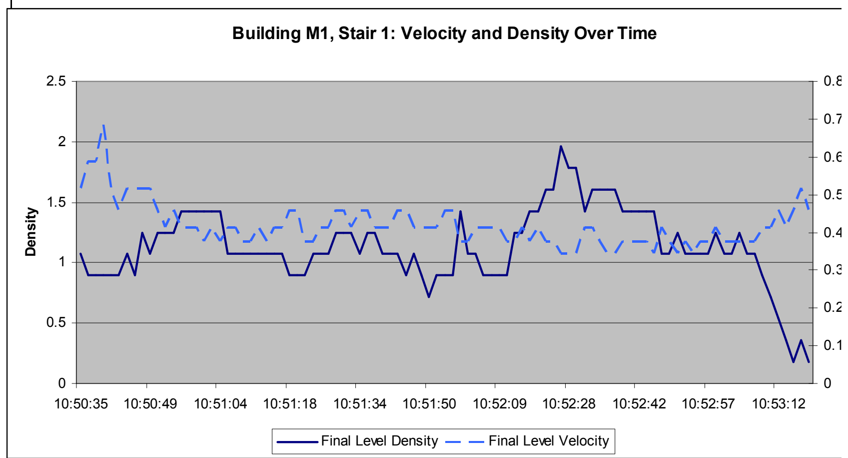
<td>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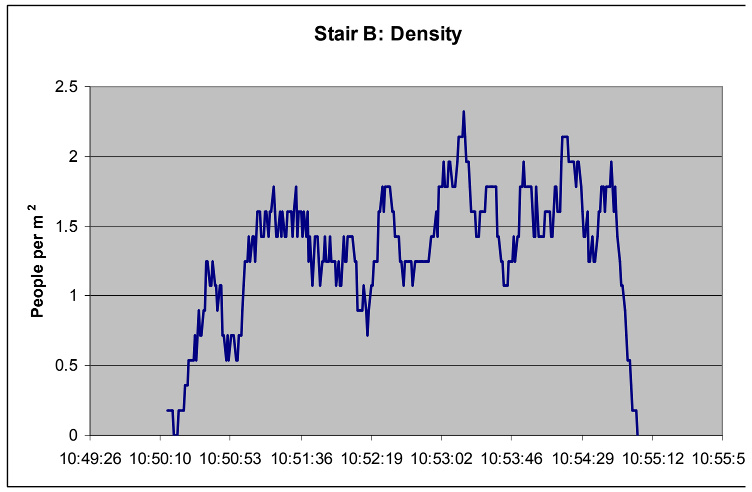
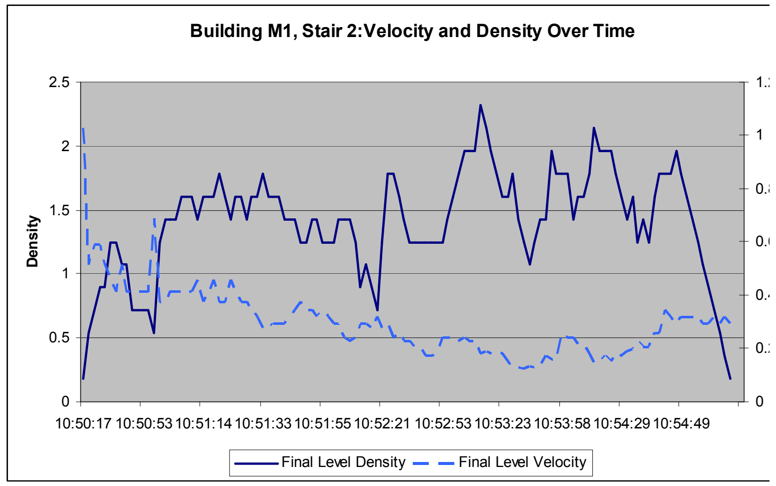
<td>


</td>
<td>Time in stair for Stair 1 (A) is approximately 3 minutes and in Stair 2</td>
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<td>R^2 = 0.2054 p<.05 ; equation y=-.0839x+0.5116</td>
<td>R^2= 0.265: p<.05: equation y -0.162x+0.5279</td>
<td>X= density and Y= velocity</td>
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<tr>
<td>STAIR ONE</td>
<td>STAIR TWO</td>
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Table A129: DENSITY AND VELOCITY BUILDING M1

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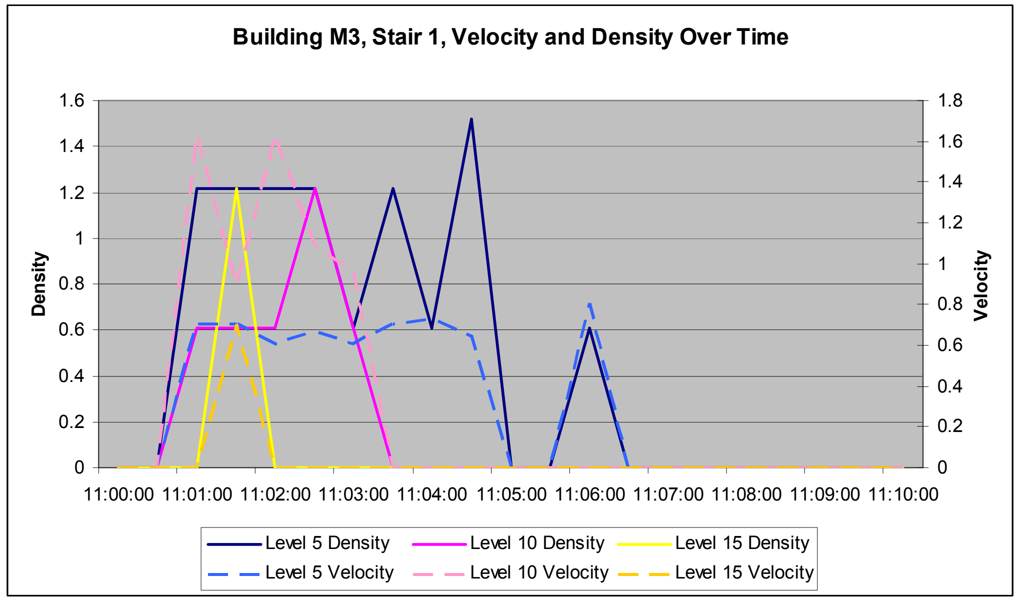

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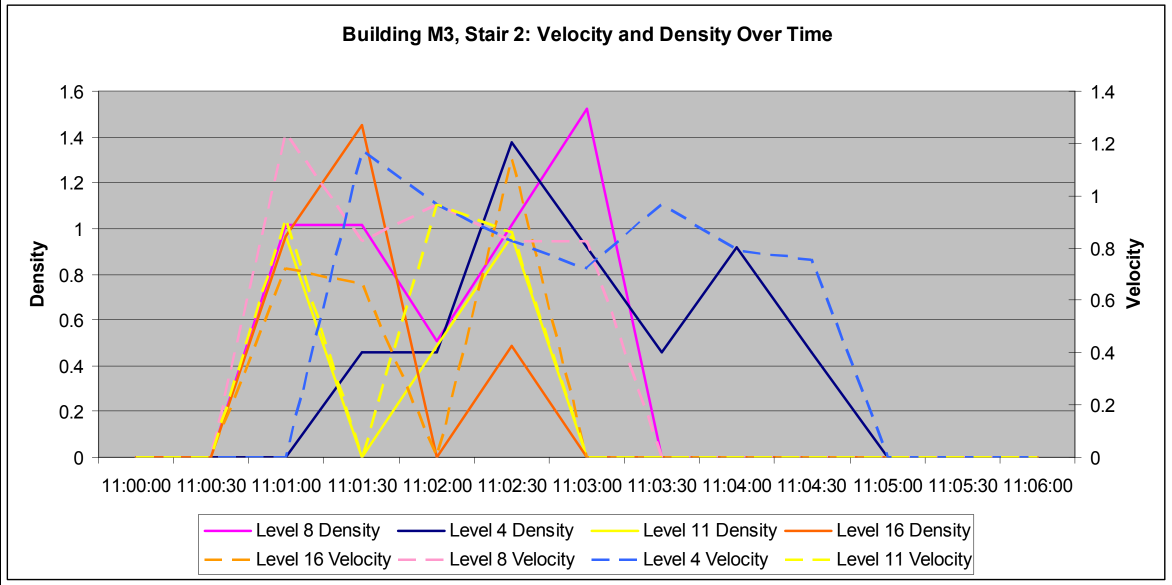

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<tr>
<td>$R^2 = 0.2312$; $p<.05$; equation $y= -.4732x+1.3222$</td>
<td>$R^2 = 0.2086$; $p<.05$; equation $y= -.0616x+0.3192$</td>
<td>X= density and Y= velocity</td>
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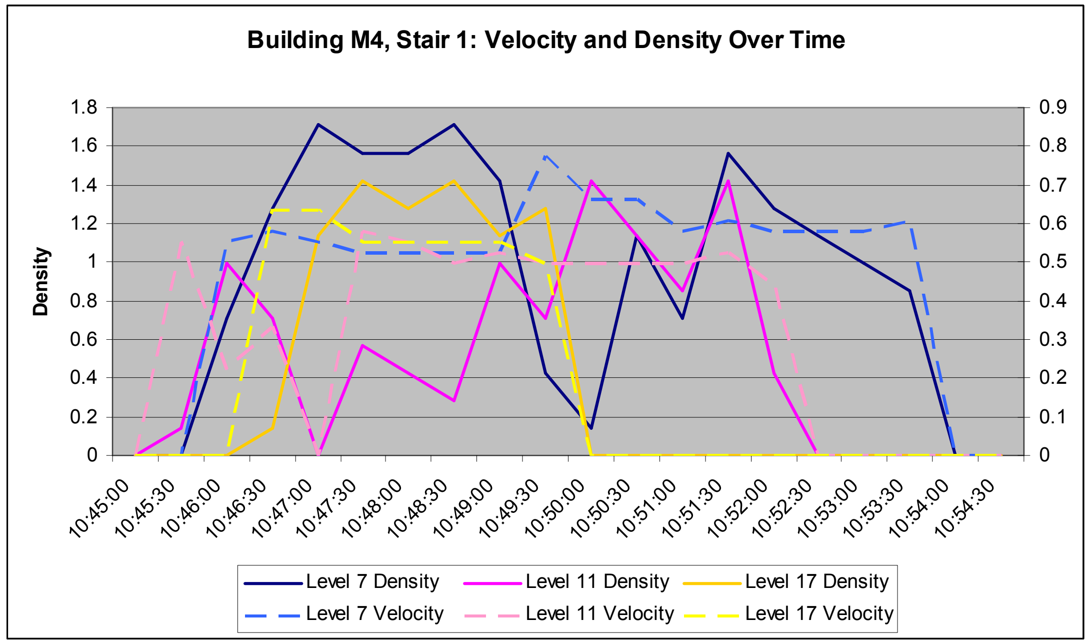

</td>
<td>INCOMPLETE DATA BUT SIMILAR TO STAIR ONE FROM OBSERVATION</td>
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<tr>
<td>$R^2 = 0..0134$ $p<.05$; equation $y=-.0227x+0.5861$</td>
<td>Same regression result</td>
<td>X= density and Y= velocity</td>
</tr>
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<td>M3/M4 velocity and density – STAIR 1</td>
<td>M3/M4 velocity and density – STAIR 2</td>
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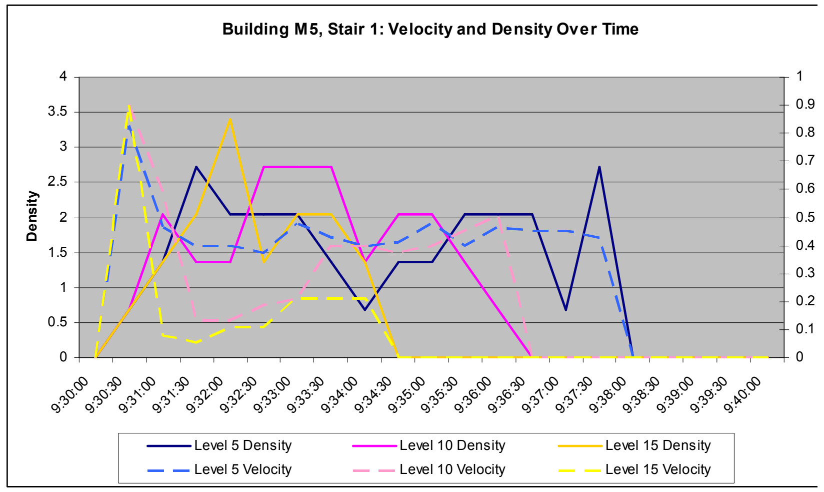
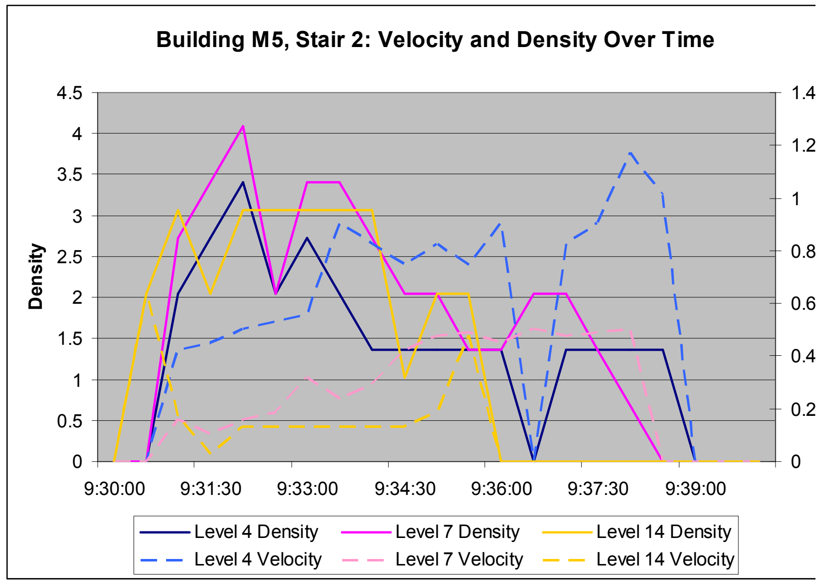
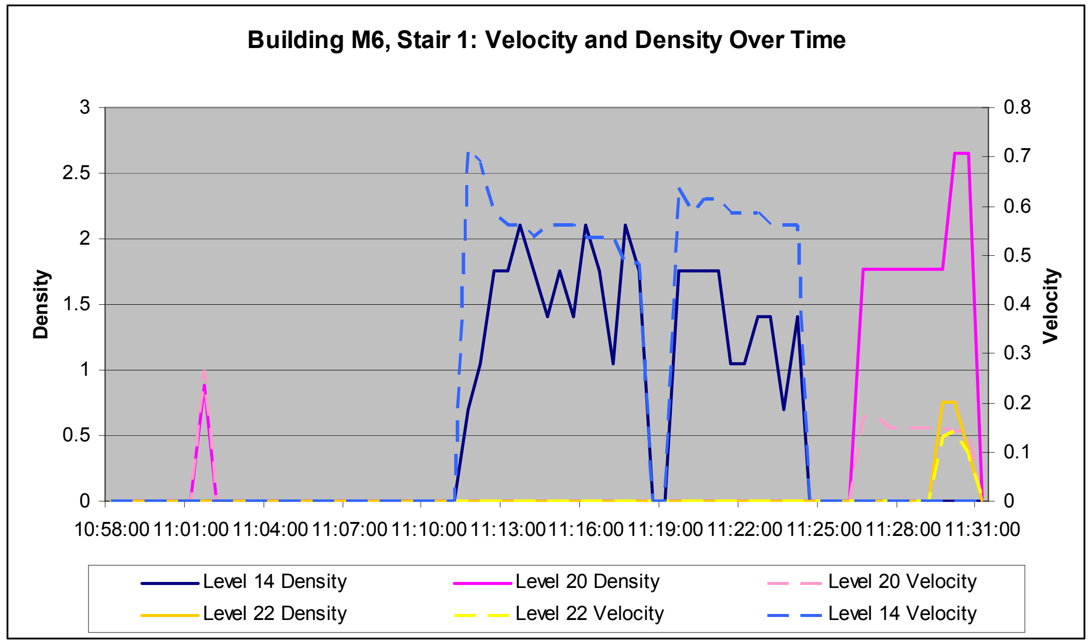
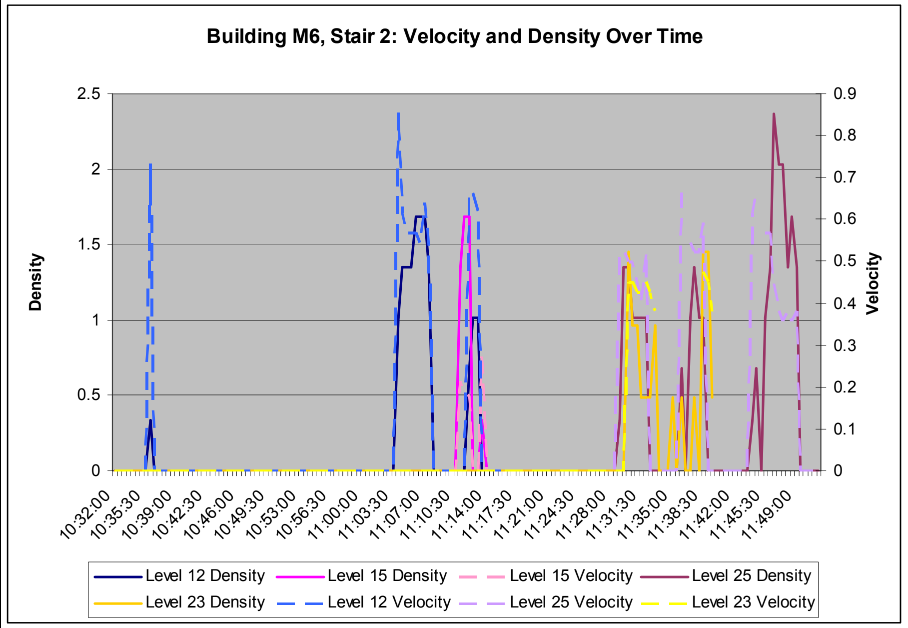
Table A130: BUILDINGS M3 AND M4 DESNITY VS VELOCITY





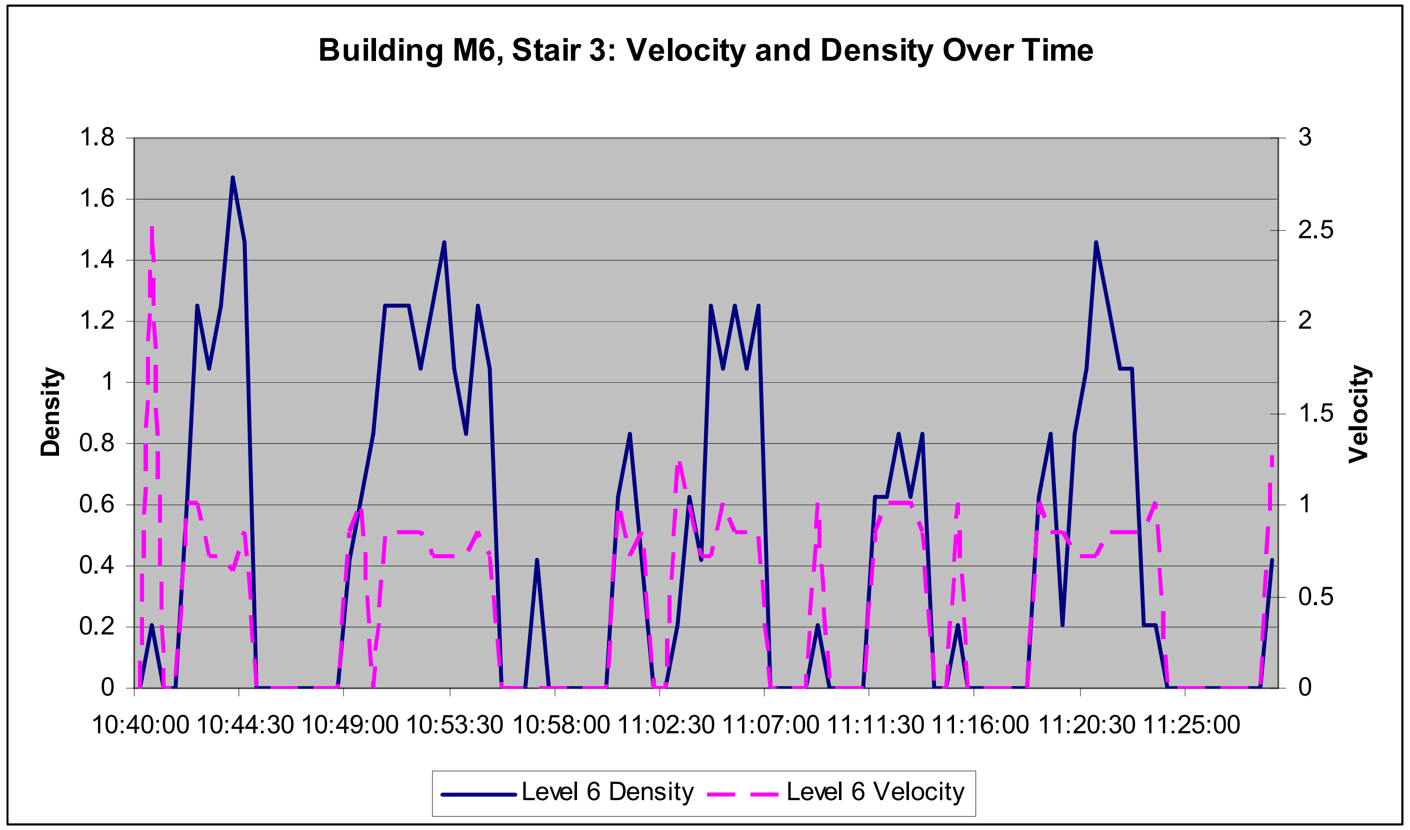
R^2= 0.2015: p<.05 Equation: y = -0.1326x + 0.6127	R^2= 0.3928: p<.05 Equation: y = -0.2239x + 0..9501





R^2= 0.0177: p<.05 Equation: y = -0.0238x + 0.6136	R^2 = 0.321; p<.05 : Equation y= -0.132x + 0.7097

Table131: BUILDINGS M5 AND M6 DENSITY AND VELOCITY



R^2 = 0.4129; p<.05: Equation y= 0.6143x + 0.1818

Table A132 BUILDING M6 STAIR 3 DENSITY AND VELOCITY

BUILDING M1: BMI TRIANGULATION						
Body Mass Index	Level	Stair 1	m/sec	Stair 2	m/sec	Comments
Underweight (<18.49)	5	1	N/o			
		1	N/o			
Normal Weight (18.5-24.99)	1	7	N/o	1	N/o	
	2	6	first 0.47; last 0.50; av 0.48	0	N/o	different groups
	4	7	first 0.66; last 0.51; av 0.58	0	N/o	different groups
	5	1	N/o	0	N/o	
	6	3	first 0.62; last 0.46; av 0.53	0	N/o	different groups
	7	4	N/o	0	N/o	
	8	3	first 0.55; last 0.48; av 0.51	0	N/o	different groups
	9	6	N/o	0	N/o	different groups
	10	5	first 0.50; last 0.74; av 0.60	0	N/o	different groups
Over Weight (25-29.99)	1	7	N/o	0	N/o	
	2	6	first 0.47; last 0.50; av 0.48	0	N/o	
	3	1	N/o	0	N/o	
	4	2	first 0.66; last 0.51; av 0.58	2	first 0.60; last 0.22; av 0.32	different groups
	6	4	first 0.62; last 0.46; av 0.53	1	first 0.65; last 0.25; av 0.36	different groups
	7	4	N/o	0	N/o	
	8	2	first 0.55; last 0.48; av 0.51	0	N/o	
	9	2	N/o	0	N/o	
	10	5	first 0.50; last 0.74; av 0.60	1	first 0.33; last 0.41; av 0.37	different groups
Obese Class 1 (30-34.99)	1	1	N/o	0	N/o	
	2	2	first 0.47; last 0.50; av 0.48 (#)	0	N/o	
	7	3	N/o	0	N/o	
	9	1	N/o	0	N/o	
Obese Class 2 (35-39.99)	1	1	N/o	1	N/o	
	4	2	first 0.66; last 0.51; av 0.58 (#)	0	N/o	different groups
	9	2	N/o	0	N/o	
Obese Class 3 (40+)	1	1	N/o	0	N/o	
	4	1	first 0.66; last 0.51; av 0.58 (#)	0	N/o	different groups
	6	1	first 0.62; last 0.46; av 0.53 (#)	0	N/o	different groups
	7	1	N/o	0	N/o	
first occupant faster than last		*(#) Descent speed above the benchmark; risk of falling*				**6/99= 6% POPULATION AT RISK**
first occupant slower than last		*(*) Descent speed within benchmark; no risk of falling*				

Table A133: Building M1 - BMI triangulation with Descent Speed

Body Mass Index	Level	Stair 1	m/sec	Stair 2	m/sec
Underweight (<18.49)	6	1	first 0.60; last 0.59; av 0.59		
Normal Weight (18.5-24.99)	1	2	first 0.69; last 0.51; av 0.61	1	N/o
	2	0	N/o	2	N/o
	3	2	first 0.68; last 0.54; av 0.61	0	N/o
	4	4	first 0.55; last 0.53; av 0.54	0	N/o
	5	1	first 0.53; last 0.59; av 0.57	0	N/o
	6	1	first 0.60; last 0.59; av 0.59	0	N/o
	7	4	N/o	1	first 0.95; last 0.70; av 0.80
	8	2	first 0.58; last 0.62; av 0.60	3	first 1.04; last 0.79; av 0.90
	10	4	0.61	0	N/o
	11	1	first 0.73; last 0.69; av 0.71	1	first 1.01; last 1.42; av 1.17
	12	0	N/o	4	first 0.84; last 0.87; av 0.85
	13	0	N/o	3	first 0.74; last 0.80; av 0.77
	14	2	first 0.69; last 0.77; av 0.73	2	N/o
	17	0	N/o	4	first 0.79; last 0.98; av 0.88
Overweight (25-29.99)	1	1	first 0.69; last 0.51; av 0.61	0	N/o
	2	1	N/o	0	N/o
	3	1	first 0.68; last 0.54; av 0.61	0	N/o
	4	4	first 0.55; last 0.53; av 0.54	0	N/o
	5	1	first 0.53; last 0.59; av 0.57	0	N/o
	7	1	N/o	4	first 0.95; last 0.70; av 0.80
	8	1	first 0.58; last 0.62; av 0.60	2	first 1.04; last 0.79; av 0.90
	10	1	0.61	0	N/o
	11	1	first 0.73; last 0.69; av 0.71	0	first 1.01; last 1.42; av 1.17
	12	1	N/o	3	first 0.84; last 0.87; av 0.85
	13	0	N/o	1	first 0.74; last 0.80; av 0.77
	14	1	first 0.69; last 0.77; av 0.73	0	N/o
	17	1	first 0.74; last 0.80; av 0.77	6	first 0.79; last 0.98; av 0.88
Obese Class 1 (30-34.99)	1	1	first 0.69; last 0.51; av 0.61 (#)	0	N/o
	4	1	first 0.55; last 0.53; av 0.54 (#)	0	N/o
	7	1	N/o	1	first 0.95; last 0.70; av 0.80 (#)
	8	0	N/o	1	first 1.04; last 0.79; av 0.90 (#)
	17	0	N/o	1	first 0.79; last 0.98; av 0.88 (#)
Obese Class 2 (35-39.99)	6	1	first 0.60; last 0.59; av 0.59 (#)	0	N/o
	7	0	N/o	1	first 0.95; last 0.70; av 0.80 (#)
	10	2	0.61 (#)	0	N/o
	11	0	N/o	1	first 1.01; last 1.42; av 1.17 (#)
	12	0	N/o	1	first 0.84; last 0.87; av 0.85 (#)
	17	1	first 0.74; last 0.80; av 0.77 (#)	1	first 0.79; last 0.98; av 0.88 (#)
Obese Class 3 (40+)	2	2	N/o		
	13	1	first 0.70; last 0.68; av 0.69 (#)		
(#) Descent speed above the benchmark; risk of falling		14/95=14.7%	first occupant faster than last		first occupant slower than last

Table A134: Building M3 - BMI triangulation with Descent Speed

Body Mass Index	Level	Stair 1	m/sec	Stair 2	m/sec
Underweight (<18.49)	23	1	first 0.50; last 0.40; av 0.44		
Normal Weight (18.5-24.99)	5	4	first 0.53; last 0.28; av 0.36	3	first 1.34; last 0.46; av 0.70
	6	1	first 0.44; last 0.27; av 0.33	0	N/o
	7	0	N/o	4	first 0.55; last 0.36; av 0.44
	8	0	N/o	4	first 0.39; last 0.41; av 0.40
	10	0	N/o	1	first 0.36; last 0.36; av 0.36
	11	2	first 0.38; last 0.31; av 0.34	0	N/o
	12	2	first 0.31; last 0.40; av 0.35	2	first 0.29; last 0.35; av 0.31
	14	1	first 0.37; last 0.46; av 0.41	1	first 0.30; last 0.30; av 0.30
	15	0	N/o	1	Ave 0.31
	19	1	first 0.45; last 0.44; av 0.45	0	N/o
	22	2	first 0.47; last 0.41; av 0.44	2	first 0.41; last 0.48; av 0.44
	23	2	first 0.50; last 0.40; av 0.44	4	first 0.37; last 0.48; av 0.41
	25	1	first 0.45; last 0.44; av 0.44	0	N/o
	26	0	N/o	2	N/o
: Overweight (25-29.99)	5	6	first 0.53; last 0.28; av 0.36	1	first 1.34; last 0.46; av 0.70
	6	0	N/o	3	first 0.67; last 0.43; av 0.52
	7	0	N/o	3	first 0.55; last 0.36; av 0.44
	8	0	N/o	6	first 0.39; last 0.41; av 0.40
	10	1	first 0.37; last 0.36; av 0.36	1	first 0.36; last 0.36; av 0.36
	11	1	first 0.38; last 0.31; av 0.34	1	first 0.29; last 0.32; av 0.30
	12	0	N/o	1	first 0.29; last 0.35; av 0.31
	21	1	first 0.47; last 0.41: av.0.44	0	N/o
	22	4	first 0.47; last 0.41; av 0.44	0	N/o
	23	1	first 0.50; last 0.40; av 0.44	2	first 0.37; last 0.48; av 0.41
	26	0	N/o	2	N/o
Obese Class 1 (30-34.99)	6	0	N/o	2	first 0.67; last 0.43; av 0.52 (#)
	9	0	N/o	1	first 0.35; last 0.35; av 0.35 (*)
	10	1	first 0.37; last 0.36; av 0.36 (*)	0	N/o
	15	0	N/o	1	0.31 (*)
Obese Class 2 (35-39.99)	8	0	N/o	1	first 0.39; last 0.41; av 0.40 (*)
	11	1	first 0.38; last 0.31; av 0.34 (*)	1	first 0.29; last 0.32; av 0.30 (*)
	23	0	N/o	1	first 0.37; last 0.48; av 0.41 (*)
Obese Class 3 (40+)	6	0	N/o	1	first 0.67; last 0.43; av 0.52 (#)
	15	1	N/o	0	N/o
	23	0	N/o	1	first 0.37; last 0.48; av 0.41 (*)
	27	0	N/o	1	N/o
#Descent speed above the benchmark – risk of falling			First faster than last		Last faster than first
3/88= 3.4%					

Table A135: Building M4 - BMI triangulation with Descent Speed

Body Mass Index	Level	Stair 1	m/sec	Stair 2	m/sec
Underweight (<18.49)	11	0	N/o	1	first 0.49; last 0.71; av 0.58
	16	1	first 0.34; last 0.41; av 0.37	0	N/o
Normal Weight (18.5-24.99)	6	0	N/o	6	first 1.23; last 0.67; av 0.87
	7	1	first 0.80; last 0.42; av 0.55	0	N/o
	8	1	first 0.47; last 0.41; av 0.44	1	first 0.88; last 0.47; av 0.62
	9	3	first 0.44; last 0.41; av 0.43	3	first 0.97; last 0.58; av 0.73
	10	2	first 0.44; last 0.41; av 0.42	2	N/o
	11	1	first 0.45; last 0.42; av 0.44	1	first 0.49; last 0.71; av 0.58
	12	1	first 0.35; last 0.42; av 0.38	2	first 0.35; last 0.55; av 0.43
	14	1	first 0.40; last 0.35; av 0.37	0	N/o
	16	2	first 0.34; last 0.41; av 0.37	3	first 0.32; last 0.33; av 0.32
	18	1	N/o	0	N/o
Overweight (25-29.99)	6	1	first 0.65; last 0.43; av 0.52	0	N/o
	8	1	first 0.47; last 0.41; av 0.44	2	first 0.88; last 0.47; av 0.62
	11	0	N/o	1	first 0.49; last 0.71; av 0.58
	12	0	N/o	1	first 0.35; last 0.55; av 0.43
	14	2	first 0.40; last 0.35; av 0.37	5	first 0.49; last 0.29; av 0.36
	15	1	first 0.37; last 0.43; av 0.40	0	N/o
	18	0	N/o	1	N/o
Obese Class 1 (30-34.99)	7	0	N/o	1	first 2.17; last 0.77; av 1.13 (#)
	8	1	first 0.47; last 0.41; av 0.44(#)	0	N/o
	11	1	first 0.45; last 0.42; av 0.44 (#)	0	N/o
	16	0	N/o	1	first 0.32; last 0.33; av 0.32 (*)
Obese Class 2 (35-39.99)	10	0	N/o	1	N/o
	11	1	first 0.45; last 0.42; av 0.44 (#)	0	N/o
first occupant faster than last			(#) Descent speed above the benchmark; risk of falling		**4/54 = 7.4%**
first occupant slower than last			(*) Descent speed within benchmark; no risk of falling		

Table A136: Building M5 - BMI triangulation with Descent Speed

Body Mass Index	**Level**	**Stair 1**	**m/sec**	**Stair 2**	**m/sec**	**Stair 3**	**m/sec**
Underweight (<18.49)	8	1	N/o		N/o	0	N/o
	13	0	N/o		N/o	1	N/o
	20	1	first 0.63; last 0.51; av 0.56		N/o	0	N/o
Normal Weight (18.5-24.99)	1	1	N/o	0	N/o	0	N/o
	2	1	N/o	1	N/o	0	N/o
	3	0	N/o	0	N/o	2	last 0.49
	5	1	N/o	0	N/o	1	N/o
	6	1	N/o	1	N/o	0	N/o
	7	0	N/o	1	N/o	1	N/o
	8	3	N/o	0	N/o	1	N/o
	9	1	N/o	2	N/o	0	N/o
	10	0	N/o	0	N/o	2	last 0.48
	11	2	first 1.11; last 0.56; av 0.74	1	N/o	1	N/o
	12	0	N/o	1	first 0.87; last 0.85; av 0.86	1	N/o
	13	2	N/o	0	N/o	1	N/o
	14	2	first 0.67; last 0.83; av 0.74	0	N/o	0	N/o
	15	0	N/o	4	first 0.71; last 0.73; av 0.72	0	N/o
	17	2	N/o	1	N/o	1	N/o
	18	1	N/o	2	N/o	1	N/o
	19	1	N/o	0	N/o	0	N/o
	20	0	N/o	1	N/o	0	N/o
	24	2	N/o	0	N/o	0	N/o
	25	0	N/o	2	first 0.65; last 0.62; av 0.64	0	N/o
	26	1	N/o	0	N/o	0	N/o
	27	0	N/o	1	first 0.56; last 0.64; av 0.60	0	N/o
	28	1	N/o	0	N/o	0	N/o
	29	0	N/o	2	first 0.58; last 0.47; av 0.52	0	N/o
	30	1	N/o	1	N/o	0	N/o
	31	1	N/o	2	first 0.55; last 0.51; av 0.53	0	N/o
	32	0	N/o	1	N/o	0	N/o

SEE CONTINUATION OF TABLE FOR M6 BMI TRIANGULATION ON NEXT PAGE

TABLE CONTINUED FROM PREVIOUS PAGE

Body Mass Index	Level	Stair 1	m/sec	Stair 2	m/sec	Stair 3	m/sec
Over Weight (25-29.99)	1	2	N/o	1	N/o	0	N/o
	2	0	N/o	1	N/o	0	N/o
	3	1	N/o	1	N/o	1	N/o
	7	0	N/o	0	N/o	2	N/o
	8	4	N/o	0	N/o	1	N/o
	9	0	N/o	1	N/o	1	N/o
	10	1	N/o	1	N/o	0	N/o
	13	1	N/o	0	N/o	0	N/o
	15	0	N/o	1	first 0.71; last 0.73; av 0.72	0	N/o
	16	0	N/o	0	N/o	2	N/o
	17	1	N/o	0	N/o	1	N/o
	18	0	N/o	1	N/o	1	N/o
	19	0	N/o	0	N/o	2	N/o
	20	0	N/o	1	last 0.57	0	N/o
	24	1	N/o	0	N/o	0	N/o
	27	0	N/o	3	first 0.56; last 0.64; av 0.60	0	N/o
	28	0	N/o	1	N/o	0	N/o
	29	1	N/o	1	first 0.58; last 0.47; av 0.52	0	N/o
	31	0	N/o	2	first 0.55; last 0.51; av 0.53	0	N/o
	32	1	N/o	1	N/o	0	N/o
Obese Class 1 (30-34.99)	2	0	N/o	1	Observer descending #	0	N/o
	5	0	N/o	1	Observer descending #	0	N/o
	8	1	N/o	0	N/o	0	N/o
	13	1	N/o	0	N/o	0	N/o
	15	0	N/o	1	first 0.71; last 0.73; av 0.72 (#)	0	N/o
	17	1	N/o	0	N/o	1	Observer descending#
	25	0	N/o	0	N/o	1	Observer descending#
	27	0	N/o	1	first 0.56; last 0.64; av 0.60 (#)	0	N/o
	28	1	N/o	0	N/o	0	N/o
	29	0	N/o	0	N/o	1	N/o
	31	0	N/o	1	first 0.55; last 0.51; av 0.53 (#)	0	N/o
	32	0	N/o	1	Observer descending #	0	N/o
Obese Class 2 (35-39.99)	5	0	N/o	1	Observer descending #	0	N/o
	6	0	N/o	1	Observer descending #	0	N/o
	13	0	N/o	1	Observer descending #	1	Observer descending#
	26	1	N/o	0	N/o	0	N/o
			12/121 = 9.9%		First faster than last		Last faster than first
(#) Descent speed above the benchmark; risk of falling							

Table A137: Building M6 - BMI triangulation with Descent Speed

Number of Health Conditions	Level	Stair 1	m/sec	Stair 2	m/sec
No Health Conditions	1	11	N/o	1	N/o
	2	9	first 0.47; last 0.50; av 0.48	0	N/o
	4	9	first 0.66; last 0.51; av 0.58	2	first 0.60; last 0.22; av 0.32
	5	2	N/o	0	N/o
	6	6	first 0.62; last 0.46; av 0.53	1	first 0.65; last 0.25; av 0.36
	7	7	N/o	0	N/o
	8	4	first 0.55; last 0.48; av 0.51	0	N/o
	9	9	N/o	0	N/o
	10	9	first 0.50; last 0.74; av 0.60	0	N/o
1 Health Condition	1	4	N/o	0	N/o
	2	5	first 0.47; last 0.50; av 0.48	0	N/o
	3	1	N/o	0	N/o
	4	3	first 0.66; last 0.51; av 0.58	0	N/o
	6	2	first 0.62; last 0.46; av 0.53	0	N/o
	7	4	N/o	0	N/o
	8	1	first 0.55; last 0.48; av 0.51	0	N/o
	9	2	N/o	0	N/o
	10	0	N/o	1	first 0.33; last 0.41; av 0.37
2 Health Conditions	1	2	N/o	1	N/o
3+ Health Conditions	7	1	N/o	0	N/o
	10	1	first 0.50; last 0.74; av 0.60	1	first 0.33; last 0.41; av 0.37
≥2 Health conditions –risk of falling		2/99 = 2%	First slower than last		
			First faster than last		

Table A138: Building M1 - ≥ 2 Health Conditions - Triangulation with Descent Speed

Number of Health Conditions	Level	Stair 1	m/sec	Stair 2	m/sec
No Health Conditions	1	4	first 0.69; last 0.51; av 0.61	1	N/o
	2	2	N/o	2	N/o
	3	2	first 0.68; last 0.54; av 0.61	0	N/o
	4	6	first 0.55; last 0.53; av 0.54	0	N/o
	5	3	first 0.53; last 0.59; av 0.57	0	N/o
	6	3	first 0.60; last 0.59; av 0.59	0	N/o
	7	5	N/o	5	first 0.95; last 0.70; av 0.80
	8	3	first 0.58; last 0.62; av 0.60	5	first 1.04; last 0.79; av 0.90
	10	6	0.61	0	N/o
	11	3	first 0.73; last 0.69; av 0.71	2	first 1.01; last 1.42; av 1.17
	12	1	N/o	8	first 0.84; last 0.87; av 0.85
	13	1	first 0.70; last 0.68; av 0.69	3	first 0.74; last 0.80; av 0.77
	14	2	first 0.69; last 0.77; av 0.73	2	N/o
	17	1	first 0.74; last 0.80; av 0.77	8	first 0.79; last 0.98; av 0.88
1 Health Condition	2	1	N/o	0	N/o
	4	3	first 0.55; last 0.53; av 0.54	0	N/o
	5	1	first 0.53; last 0.59; av 0.57	0	N/o
	7	1	N/o	2	first 0.95; last 0.70; av 0.80
	8	0	N/o	1	first 1.04; last 0.79; av 0.90
	13	0	N/o	1	first 0.74; last 0.80; av 0.77
	14	1	first 0.69; last 0.77; av 0.73	0	N/o
	17	0	N/o	2	first 0.79; last 0.98; av 0.88
3+ Health Conditions	3	1	first 0.68; last 0.54; av 0.61	0	N/o
	4	1	first 0.55; last 0.53; av 0.54	0	N/o
	10	1	first 0.68; last 0.54; av 0.61	0	N/o
	17	1	first 0.74; last 0.80; av 0.77	1	first 0.79; last 0.98; av 0.88
≥ 2 Health Conditions = risk of falling			First faster than last		
5/96 = 5.2%			First slower than last		

Table A139: Building M3 - ≥ 2 Health Conditions - Triangulation with Descent Speed

Number of Health Conditions	Level	Stair 1	m/sec	Stair 2	m/sec
No Health Conditions	5	6	first 0.53; last 0.28; av 0.36	0	N/o
	6	1	first 0.44; last 0.27; av 0.33	4	first 0.67; last 0.43; av 0.52
	7	0	N/o	5	first 0.55; last 0.36; av 0.44
	8	0	N/o	6	first 0.39; last 0.41; av 0.40
	9	0	N/o	1	N/o
	10	1	first 0.37; last 0.36; av 0.36	1	first 0.36; last 0.36; av 0.36
	11	3	first 0.38; last 0.31; av 0.34	1	first 0.29; last 0.32; av 0.30
	12	1	first 0.31; last 0.40; av 0.35	2	first 0.29; last 0.35; av 0.31
	15	0	N/o	1	first 0.29; last 0.35; av 0.31
	21	1	first 0.47; last 0.41; av. 0.44	0	N/o
	22	5	first 0.47; last 0.41; av 0.44	2	first 0.41; last 0.48; av 0.44
	23	2	first 0.50; last 0.40; av 0.44	6	first 0.37; last 0.48; av 0.41
	25	1	first 0.45; last 0.44; av 0.44	0	N/o
	26	0	N/o	3	N/o
	27	0	N/o	1	N/o
1 Health Condition	5	2	first 0.53; last 0.28; av 0.36	3	first 1.34; last 0.46; av 0.70
	7	0	N/o	1	first 0.55; last 0.36; av 0.44
	8	0	N/o	3	first 0.39; last 0.41; av 0.40
	11	0	N/o	1	first 0.29; last 0.32; av 0.30
	12	1	first 0.31; last 0.40; av 0.35	1	first 0.29; last 0.35; av 0.31
	14	1	first 0.37; last 0.46; av 0.41	1	first 0.30; last 0.30; av 0.30
	19	1	first 0.45; last 0.44; av 0.45	0	N/o
	23	1	first 0.50; last 0.40; av 0.44	1	first 0.37; last 0.48; av 0.41
	26	0	N/o	1	N/o
2 Health Conditions	6	0	N/o	1	first 0.67; last 0.43; av 0.52
	10	1	first 0.37; last 0.36; av 0.36	1	first 0.36; last 0.36; av 0.36
	15	0	N/o	2	0.31
	22	2	first 0.47; last 0.41; av 0.44	0	N/o
	23	1	first 0.50; last 0.40; av 0.44	1	first 0.37; last 0.48; av 0.41
3+ Health Conditions	5	2	first 0.53; last 0.28; av 0.36	1	first 1.34; last 0.46; av 0.70
	6	0	N/o	1	first 0.67; last 0.43; av 0.52
	7	0	N/o	1	first 0.55; last 0.36; av 0.44
	8	0	N/o	2	first 0.39; last 0.41; av 0.40
	11	1	first 0.38; last 0.31; av 0.34	0	N/o
	15	1	N/o	1	first 0.38; last 0.31; av 0.34
≥ 2 Health Conditions = risk of falling			First faster than last		
3/90 = 3.3%			First slower than last		

Table A140: Building M4 - ≥ 2 Health Conditions - Triangulation with Descent Speed

Number of Health Conditions	Level	Stair 1	m/sec	Stair 2	m/sec
No Health Conditions	6	1	first 0.65; last 0.43; av 0.52	3	first 1.23; last 0.67; av 0.87
	7	1	first 0.80; last 0.42; av 0.55	0	N/o
	8	3	first 0.47; last 0.41; av 0.44	1	first 0.88; last 0.47; av 0.62
	9	1	first 0.44; last 0.41; av 0.43	1	first 0.97; last 0.58; av 0.73
	10	2	first 0.44; last 0.41; av 0.42	3	N/o
	11	1	first 0.45; last 0.42; av 0.44	2	first 0.49; last 0.71; av 0.58
	12	1	first 0.35; last 0.42; av 0.38	2	first 0.35; last 0.55; av 0.43
	14	3	first 0.40; last 0.35; av 0.37	3	first 0.49; last 0.29; av 0.36
	15	1	first 0.37; last 0.43; av 0.40	0	N/o
	16	3	first 0.34; last 0.41; av 0.37	1	first 0.32; last 0.33; av 0.32
	18	0	N/o	1	N/o
1 Health Condition	6	0	N/o	3	first 1.23; last 0.67; av 0.87
	7	0	N/o	1	first 2.17; last 0.77; av 1.13
	8	0	N/o	2	first 0.88; last 0.47; av 0.62
	9	2	first 0.44; last 0.41; av 0.43	2	first 0.97; last 0.58; av 0.73
	11	1	first 0.45; last 0.42; av 0.44	0	N/o
	12	0	N/o	1	first 0.35; last 0.55; av 0.43
	16	0	N/o	1	first 0.32; last 0.33; av 0.32
	18	1	N/o	0	N/o
2 Health Conditions	11	1	first 0.45; last 0.42; av 0.44	1	first 0.49; last 0.71; av 0.58
	14		first 0.40; last 0.35; av 0.37	1	first 0.49; last 0.29; av 0.36
	16		first 0.34; last 0.41; av 0.37	2	first 0.32; last 0.33; av 0.32
3+ Health Conditions	11	1	first 0.45; last 0.42; av 0.44	0	N/o
	14	0	N/o	1	first 0.49; last 0.29; av 0.36
≥ 2 Health Conditions = risk of falling		**3/55 = 5.5%**	First faster than last		
			First slower than last		

Table A141: Building M5 - ≥ 2 Health Conditions - Triangulation with Descent Speed

Number of Health Conditions	Level	Stair 1	m/sec	Stair 2	m/sec	Stair 3	m/sec
No Health Conditions	1	2	N/o	1	N/o	0	N/o
	2	1	N/o	2	N/o	1	N/o
	3	0	N/o	1	N/o	2	N/o
	5	0	N/o	1	N/o	1	N/o
	6	1	N/o	2	N/o	0	N/o
	7	0	N/o	1	N/o	0	N/o
	8	9	N/o	0	N/o	2	N/o
	9	0	N/o	3	N/o	1	N/o
	10	1	N/o	1	N/o	2	N/o
	11	2	first 1.11; last 0.56; av 0.74	1	N/o	1	N/o
	12	0	N/o	1	first 0.87; last 0.85; av 0.86	2	N/o
	13	2	N/o	0	N/o	1	N/o
	14	2	first 0.67; last 0.83; av 0.74	0	N/o	0	N/o
	15	0	N/o	4	first 0.71; last 0.73; av 0.72	0	N/o
	16	0	N/o	0	N/o	1	N/o
	17	3	N/o	1	N/o	3	N/o
	18	1	N/o	3	N/o	2	N/o
	19	1	N/o	0	N/o	1	N/o
	20	1	first 0.63; last 0.51; av 0.56	1	N/o	0	N/o
	24	3	N/o	0	N/o	0	N/o
	25	0	N/o	2	first 0.65; last 0.62; av 0.64	1	N/o
	26	1	N/o	0	N/o	0	N/o
	27	0	N/o	4	first 0.56; last 0.64; av 0.60	0	N/o
	28	2	N/o	1	N/o	0	N/o
	29	1	N/o	2	first 0.58; last 0.47; av 0.52	1	N/o
	30	1	N/o	1	N/o	0	N/o
	31	1	N/o	2	first 0.55; last 0.51; av 0.53	0	N/o
	32	0	N/o	2	N/o	0	N/o

HEALTH CONDITION TRIANGULATION TABLE FOR M6 FOLLOWS NEXT PAGE

CONTINUATION OF HEALTH CONDITION TRIANGULATION TABLE FOR M6 FROM PREVIOUS PAGE							
Number of Health Conditions	Level	Stair 1	m/sec	Stair 2	m/sec	Stair 3	m/sec
1 Health Condition	1	1	N/o	0	N/o	0	N/o
	2	0	N/o	1	N/o	0	N/o
	3	1	N/o	0	N/o	1	N/o
	5	1	N/o	1	N/o	0	N/o
	7	0	N/o	0	N/o	3	N/o
	8	0	N/o	0	N/o	1	N/o
	9	1	N/o	1	N/o	0	N/o
	13	2	N/o	0	N/o	0	N/o
	15	0	N/o	1	first 0.71; last 0.73; av 0.72	0	N/o
	16	0	N/o	0	N/o	1	N/o
	17	1	N/o	0	N/o	0	N/o
	19	0	N/o	0	N/o	1	N/o
	20	0	first 0.63; last 0.51; av 0.56	1	N/o	0	N/o
	26	1	N/o	0	N/o	0	N/o
	27	0	N/o	1	first 0.56; last 0.64; av 0.60	0	N/o
	29	0	N/o	1	first 0.58; last 0.47; av 0.52	0	N/o
	31	0	N/o	4	first 0.55; last 0.51; av 0.53	0	N/o
	32	1	N/o	0	N/o	0	N/o
2 Health Condition	13	0	N/o	0	N/o	1	Observer descending
	15	0	N/o	1	first 0.71; last 0.73; av 0.72	0	N/o
	26	0	N/o	0	N/o	1	Observer descending
	30	2	N/o	0	N/o	0	N/o
	32	0	N/o	1	Observer descending	0	Observer descending
	20	2	Observer descending	2	Observer descending	2	Observer descending
3+ Health Conditions	13	0	N/o	0	N/o	1	Observer descending
≥ 2 Health Conditions = risk of falling					First faster than last		
			11/134 = 8.2%		First slower than last		

Table A142 Building M6 - ≥ 2 Health Conditions - Triangulation with Descent Speed:

BUILDING NUMBER	All classes BMI	BMI>35	≥ 2 Health Conditions	**R^2**	Masked by density
	% age population	% population	%age population		
M1	6.0	4.0	2	0.23	23% could have been masked – reduced stair width where scissor stairs link into common passage
M2	15.65	12.1	3.3	estimated	Not measured
M3	14.7	9.0	5.2	0.21	21% could have been masked
M4	3.4	1.1	3.3	0.01	
M5	7.4	1.8	5.5	0.3	30% could have been masked – delays due to extensive merging
M6	9.9	3.3	8.2	0.3*	30% could have been masked – delays due to 3 storeys of ascent

** M6 – R^2 averaged across three stairs*   *Indicates Buildings in which Falls occurred as defined by Tinnetti et al (1988).*

Table A143: BMI and Functional Limitation Falling Risk – Derived from Comparison with Fuller Figure and Mature Age Focus Group Benchmarks

BUILDING NUMBER	Group formation	Merging pattern	Range in descent velocities	**R^2**	Comments
M1		Offset to right – occupants turn and merge door is recessed.	Minimum = 0.12m/s Maximum = 1.05m/s Average = 0.38m/s	0.23	
M2		As per M1	Note measured but observer estimated 0.2 – 0.6m/s	estimated	
M3		Door at right angles to flight on left but 895 forward of last riser. Two columns can merge in parallel pattern.	Minimum = 0.2m/s Maximum = 1.25m/s Average = 0.68m/s	0.21	
M4		Door at right angles to flight on left flow of descending column is interrupted.	Minimum = 0.28m/s Maximum = 1.34m/s Average = 0.44m/s	0.01	
M5		As per M3	Minimum = 0.29m/s Maximum = 1.15m/s Average = 0.51m/s	0.3	
M6		Door directly opposite and obstructs so that people will defer.	Minimum = 0.29m/s Maximum = 1.3m/s Average = 0.6m/s	0.3*	

TableA144: Triangulation Schedule – Group formation and Descent Velocities

Conditions on stair	Level	Stair 1	Comments	Stair 2	Comments
Alone	1	2	Not verified	1	Not verified
	2	1	Verified	0	No response
	4	4	Verified	1	Verified
	5	1	Not verified	0	Not verified
	6	1	Verified	1	Verified
	7	2	Not verified	0	Not verified
	8	2	Verified	0	No response
	9	4	Not verified	0	No response
	10	5	Verified	0	No response
Few others around	1	14	Not verified	1	Not verified
	2	12	Verified	0	No response
	3	1	Not verified	0	No response
	4	8	Verified	1	Verified
	5	1	Not verified	0	No response
	6	7	Verified	0	No response
	7	10	Not verified	0	No response
	8	3	Verified	0	No response
	9	7	Not verified	0	No response
	10	4	Verified	0	No response
Crowded but moving	1	1	Not verified	0	Not verified
Very crowded and slow	10	1	Not verified		
Percentage verified by observation	48%				

Entered stairs with friend	Level	Stair 1	Comments	Stair 2	Comments
No	1	10	Not verified	1	Not verified
	2	13	Verified	0	No response
	3	1	Not verified	0	No response
	4	7	Verified	2	Verified
	5	1	Not verified	0	No response
	6	5	Verified	0	No response
	7	7	Not verified	0	No response
	8	4	Verified	0	No response
	9	6	Not verified	0	No response
	10	7	Verified	1	Verified
Yes	1	7	Not verified	1	Not verified
	2	1	Not verified	0	No response
	4	4	Not verified	0	No response
	5	1	Not verified	0	No response
	6	3	Verified	1	Verified
	7	5	Not verified	0	No response
	8	1	Verified	0	No response
	9	4	Not verified	0	No response
	10	3	Not verified	0	No response
Percentage verified by observation	46%				

Table A145: M1 Triangulation Schedule – Group Formation Verification and Perceived Density

Entered stair with friend	Level	Stair1		Stair 2	Comment
No	2	2	Not verified	1	Not verified
	3	1	Verified	0	Not verified
	4	4	Verified	0	Not verified
	6	1	Verified	0	Not verified
	7	1	Not verified	4	Verified
	8	3	Verified	6	Verified
	10	3	Not verified	0	Not verified
	11	2	Verified	2	Verified
	12	0	Not verified	6	Verified
	13	1	Verified	2	Verified
	14	2	Verified	0	Not verified
	17	2	Verified	7	Verified
Yes	1	4	Verified	1	Not verified
	2	1	Not verified	1	Not verified
	3	2	Verified	0	Not verified
	4	6	Not verified	0	Not verified
	5	4	Verified	0	Not verified
	6	2	Not verified	0	Not verified
	7	5	Not verified	3	Not verified
	10	4	Not verified	0	Not verified
	11	1	Verified	0	Verified
	12	1	Not verified	2	Not verified
	13	0	Verified	2	Not verified
	14	1	Not verified	2	Not verified
	17	0	No response	4	Verified

Percentage verified by observation: 60.4%

Table A146: M3 Triangulation Schedule – Group Formation Verification –stair entry

Entered stairs with friend	Level	Stair 1		Stair 2	Comments
No	5	4	Verified	3	Verified
	6	1	Verified	3	Verified
	7	0	No response	2	Verified
	8	0	No response	5	Verified
	10	1	Verified	1	Verified
	11	2	Verified	1	Verified
	12	1	Verified	3	Verified
	14	1	Verified	0	No response
	15	1	Not verified	2	Not verified
	22	1	Verified	1	Verified
	23	2	Verified	2	Verified
	26	0	No response	2	Not verified
Yes	5	6	Verified	1	Verified
	6	0	No response	3	Verified
	7	0	No response	4	Verified
	8	0	No response	6	Verified
	9	0	No response	1	Verified
	10	1	Verified	1	Verified
	11	2	Verified	1	Verified
	12	1	Verified	0	No response
	14	0	No response	1	Verified
	15	0	Not verified	1	Not verified
	19	1	Verified	0	No response
	21	1	Verified	0	No response
	22	6	Verified	1	Verified
	23	2	Verified	6	Verified
	25	1	Verified	0	Not verified
	26	0	No response	2	Not verified
	27	0	No response	1	Not verified

Percentage verified by observation 80%

Table A147: M4 Triangulation Schedule – Group formation Verification – stair entry

Conditions in Stair	Level	Stair 1	Comments	Stair 2	Comments	
Alone	6	1	Verified	0	Not verified	
	7	1	Not verified	0	No response	
	10	2	Not verified	0	No response	
	11	1	Verified	0	No response	
	12	1	Not verified	0	No response	
	13	1	Verified	0	No response	
	14	1	Verified	0	No response	
	17	0	No response	1	Verified	
Few others around	1	4	Verified	0	Not verified	
	2	3	Not verified	2	Not verified	
	3	2	Verified	0	Not verified	
	4	10	Verified	0	Not verified	
	5	3	Verified	0	Not verified	
	6	2	Verified	0	Not verified	
	7	5	Not verified	4	Verified	
	8	2	Verified	3	Verified	
	10	5	Not verified	0	Not verified	
	11	2	Verified	1	Verified	
	12	0	No response	8	Verified	
	13	0	No response	4	Verified	
	14	2	Verified	2	Not verified	
	17	1	Verified	7	Verified	
Crowded but moving	1	0	No response	1	Not verified	
	3	1	Not verified	0	Not verified	
	7	0	Not verified	3	Not verified	
	8	1	Verified	3	Not verified	
	11	0	No response	1	Verified	
	17	1	Verified	2	Verified	
Very crowded and slow	5	1	Verified	0	Not verified	
	17	0	No response	1	Verified	

Conditions in stair	Level	Stair 1		Stair 2	Comments
Alone	8	0	No response	3	Verified
	9	0	No response	1	Verified
	10	1	Not verified	1	Verified
	11	3	Verified	1	Verified
	12	1	Verified	1	Verified
	14	1	Verified	0	No response
	15	1	Not verified	3	Not verified
	21	1	Verified	0	No response
	22	3	Verified	0	No response
	23	2	Verified	4	Verified
Few others around	5	9	Verified	4	Verified
	6	1	Verified	6	Verified
	7	0	No response	7	Verified
	8	0	No response	8	Verified
	10	1	Verified	1	Verified
	11	1	Verified	1	Verified
	12	1	Verified	2	Verified
	14	0	No response	1	Verified
	19	1	Verified	0	Verified
	22	4	Verified	2	Verified
	23	2	Verified	3	Verified
	25	1	Verified	0	No response
	26	0	No response	4	Not verified
	27	0	No response	1	Not verified
Crowded but moving	5	1	Not verified	0	No response
	23	0	No response	1	Verified

Table A148: M3 Triangulation Schedule – Group Formation Verification: Percentage verified by observation 70% **Table A149: M4 Triangulation Schedule – Perceived Conditions:** Percentage verified by observation 89%

(These tables are continued on the next page)

Conditions in Stairs	Level	Stair 1	Comments	Stair 2	Comments
Very crowded and slow	6	1	Verified	5	Verified
	7	0	No response	1	Verified
	8	2	Verified	3	Verified
	9	2	Verified	3	Verified
	10	1	Verified	2	Not verified
	11	2	Verified	3	Verified
	12	0	No response	2	Verified
	14	3	Verified	5	Verified
	15	1	Verified	0	No response
	16	3	Verified	4	Verified
	18	1	Not verified	1	Not verified
Crowded but moving well	6	0	No response	1	Verified
	7	1	Verified	0	No response
	8	1	Verified	0	No response
	9	1	Verified	0	No response
	10	1	Verified	1	Not verified
	11	1	Verified	0	No response
	12	1	Not verified	1	Not verified

Conditions in the stair	Level	Stair 1	Comments	Stair 2	Comments	Stair 3	Comments
Very crowded and slow	3	0	Not verified	0	Not verified	2	Not verified
	5	1	Not verified	0	Not verified	0	Not verified
	8	1	Not verified	0	Not verified	0	Not verified
	11	1	Not verified	0	Not verified	0	Not verified
	17	0	Not verified	0	Not verified	1	Not verified
	20	0	No response	1	Not verified	0	Not verified
	29	0	Not verified	0	No response	1	Not verified
		3		1		4	
Crowded but moving well	1	3	Not verified	1	Not verified	0	Not verified
	2	1	Not verified	2	Not verified	0	Not verified
	3	1	Not verified	0	Not verified	1	Not verified
	5	0	Not verified	2	Not verified	1	Not verified
	6	1	Not verified	2	Not verified	0	Not verified
	7	0	Not verified	1	Not verified	2	Verified
	8	8	Not verified	0	Not verified	3	Not verified
	9	1	Not verified	2	Not verified	0	Not verified
	10	1	Not verified	1	Not verified	2	Verified
	11	1	Verified	0	Not verified	1	Not verified
	12	0	No response	1	Not verified	2	Not verified
	13	4	Not verified	0	No response	3	Verified
	14	2	Verified	0	Not verified	0	Not verified
	15	0	Not verified	5	Verified	0	Not verified
	16	0	Not verified	0	Not verified	2	Verified
	17	3	Not verified	1	Not verified	1	Not verified
	18	1	Not verified	3	Not verified	1	Not verified
	19	1	Not verified	0	Not verified	2	Verified
	20	1	Verified	1	Not verified	0	Not verified

Conditions in Stairs	Level	Stair 1	Comments	Stair 2	Comments

Percentage verified by observation 87%

Table A150: M5 Triangulation Schedule – Perceived Conditions

Conditions in the stair	Level	Stair 1	Comments	Stair 2	Comments	Stair 3	Comments
	24	3	Not verified	0	Not verified	0	Not verified
	25	0	Not verified	2	Verified	1	Not verified
	26	2	Not verified	0	Not verified	0	Not verified
	27	0	Not verified	5	Verified	0	Not verified
	28	1	Not verified	1	Not verified	0	Not verified
	29	1	Not verified	3	Verified	0	Not verified
	30	1	Not verified	0	Not verified	0	Not verified
	31	1	Not verified	4	Verified	0	Not verified
	32	1	Verified	0	Not verified	0	Not verified
Few others around	2	0	No response	1	Not verified	1	Not verified
	3	0	No response	1	Not verified	0	Not verified
	9	0	No response	2	Not verified	1	Not verified
	11	0	No response	1	Not verified	0	Not verified
	15	0	No response	1	Verified	0	Not verified
	17	1	Not verified	0	Not verified	1	Not verified
	18	0	No response	0	Not verified	1	Not verified
	26	0	No response	0	Not verified	1	Not verified
	28	1	Not verified	0	Not verified	0	Not verified
	30	2	Not verified	1	Not verified	0	Not verified
	31	0	No response	2	Verified	0	Not verified
	32	0	No response	2	Not verified	0	Not verified
		4		11		5	

Percentage verified by observation 30%

Table A151: M6 Triangulation Schedule – Perceived Conditions

Entered the stairs with friend	Level	Stair 1	Comments	Stair 2	Comments
No	6	1	Verified	5	Verified
	7	1	Verified	1	Verified
	8	2	Verified	3	Verified
	9	2	Verified	3	Verified
	10	2	Verified	3	Not verified
	11	3	Verified	2	Verified
	12	0	No response	1	Verified
	14	3	Verified	4	Verified
	16	3	Verified	2	Verified
Yes	6	0	No response	1	Verified
	8	1	Verified	0	Verified
	9	1	Verified	0	Not verified
	11	0	No response	1	Verified
	12	1	Verified	2	Verified
	14	0	No response	1	Verified
	15	1	Verified	0	Verified
	16	0	No response	2	Verified
	18	1	Not verified	1	Not verified
		22		32	

Entered the stairs with friend	Level	Stair 1	Comments
No	1	1	Not verified
	2	1	Not verified
	3	0	Not verified
	5	1	Not verified
	7	0	Not verified
	8	5	Not verified
	9	1	Not verified
	10	0	Not verified
	11	0	Not verified
	12	0	Not verified
	13	2	Not verified
	14	1	Not verified
	16	0	Not verified
	17	1	Not verified
	18	1	Not verified
	19	0	Not verified
	24	1	Not verified
	26	1	Not verified
	27	0	Not verified
	28	2	Not verified
	29	1	Not verified
	30	1	Not verified
	31	0	Not verified
Yes	1	2	Not verified
	2	0	Not verified
	3	0	Not verified
	5	0	Not verified
	6	1	Not verified
	7	0	Not verified
	8	4	Not verified
	9	0	Not verified
	10	1	Verified
	11	2	Not verified
	13	2	Not verified
	14	1	Not verified
	15	0	Not verified
	17	3	Not verified
	18	0	Not verified
	19	1	Not verified
	20	1	Verified

Entered the stairs with friend	Level	Stair 1	Comments	Stair 2	Comments

Table A152: Triangulation Schedule – Group formation Percentage verified by observation 96%

Entered the stairs with friend	Level	Stair 1	Comments
	24	2	Not verified
	25	0	Not verified
	26	1	Not verified
	27	0	Not verified
	28	0	Not verified
	29	0	Not verified
	30	2	Not verified
	31	1	Verified
	32	1	Verified

Table A153: Triangulation Schedule – Group formation Percentage verified by observation