International Journal of Building Pathology and Adaptation

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Journal:	*International Journal of Building Pathology and Adaptation*
Manuscript ID	IJBPA-08-2017-0033.R3
Manuscript Type:	Original Article
Keywords:	evacuation, lifts, egress, human behaviour, decisions, multi-storey

Multi-storey residential buildings and occupant's behaviour during fire evacuation in the UK: Factors relevant to the development of evacuation strategies.

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Abstract

Purpose – The paper aims to investigate human behaviour during fire evacuations in multi-storey residential buildings through a focus on the challenges and obstacles that occupants face. Any variations in response behaviours that are relevant to the evacuation strategies/plans in the UK context of occupancy typical of multi-storey buildings in large cities.

Design/methodology/approach – A literature review was conducted to identify the factors occupants face and also the decision-making of occupants regarding methods of egress. A mixed research method was adopted using interviews and a questionnaire survey. The findings from the interviews and survey are benchmarked against the information gathered from the literature review.

Findings – The paper identifies various challenges that occupants face when evacuating a multi-storey residential building. In terms of the decision-making process, the research results evidence that occupants could be given more information on the evacuation procedures within their specific building. The paper also finds that occupants remain reluctant to use a lift during evacuation in fire event, irrespective of any signage clearly stating that is appropriate to do so in the context of modern lift technology.

Originality/Value – This paper contributes to the body of knowledge available on the evacuation of multi-storey buildings located in large cities within the UK, outlining potential areas for future research, focused on providing an insight of the behavioural decisions made by the occupants make when evacuating a building in the event of a fire.

Keywords - Evacuation; lifts; egress; human behaviour; decisions; multi-storey

Introduction

Fire safety has consistently been a vital consideration when designing multi-storey buildings and, given the specific environment of such buildings, human behaviour during an evacuation process has long been considered a key factor in a successful evacuation (Proulx, 2002). Sekizawa *et al* (1999) suggested that some key factors are the method of which occupants react to fire cues, the motives they are given to commence evacuating, and the choice of evacuation route (typically choosing their usual route of moving around the building or a route identified as being ‘safe’ rather than one that was close). While there is a considerable body of literature relevant to the evacuation of multi-storey buildings, some of this is inevitably dated, particularly in the context of materials development, enhancements to existing technologies, emerging new technologies and a deeper understanding of the psychology of human behaviour, particularly in the context of group dynamics. Ronchi and Nilsson (2013), for example, considered not only the individual use of egress components but also the combined use of such egress components as stairwells and elevators along with other means of escape that would not be typically regarded as ‘traditional’ (sky-bridges, helicopters, etc.). However, Nillson and Kinteder’s (2015) postulates that data on the behaviour of occupants in a fire situation are generally collected using case studies is consistent with the majority of the literature reviewed. Nillson and Kintender further suggest, that controlled experiments can also be used to establish relationships in this context. In addition, the use of interview techniques, as used by Shields *et al* (2009), appears to be a relatively common method used in fire evacuation occupant behaviour studies.

Human behaviour within a fire has been examined through both the review of past evacuation situations, and simulations. Past evacuations which suggests that any decisions made within the conditions are a result of a decision-making process and not based on random actions (Kuligowski, 2009) and the use of evacuation models that can predict occupant evacuation behaviour. In addition to this, Proulx (2001) opines that the behaviour of the occupants will depend on the characteristics of not only the occupant, but also the building and the fire. Proulx (2001) further states that despite adequate fire safety systems being in place, they can often fail due to inaccurate predictions and expectations of how occupants will behave during a fire. Barber (2010) asserted that occupants’ behaviour differs when they class themselves as being at ‘home’, at ‘work’ or in a social space; when occupants regard themselves as being at ‘home’ they may show a reluctance to evacuate what they perceive to be a safe space until such point as they are sufficiently motivated by a perception of being directly threatened by a fire.

Using stairs as the only route of egress during a fire can lower the evacuation speed as well as tire the occupants especially the elderly and sick (Chen *et al* 2014). This theory is supported by Heyes (2009) who explains that during an evacuation of a multi-storey building, using only stairs can be impractical due to the ageing population and obesity problems within the

UK. To improve this problem, lifts have been proposed and used as methods of egress in multi-storey buildings. Galea (2014) suggests that past studies show that building evacuation speed can be increased by 50% through the combination of lifts and stairs. However, this figure is based on an assumption that if lifts are available then they will actually be used by occupants as a means of egress during an evacuation. This assumption can be dangerous, as Noordermeer (2010) suggests that various factors must also be considered such as how people respond to an emergency, how they interpret the information and directions given and will the fire escapes be used for the intended purposes.

This paper will examine the possible behavioural decisions occupants could make when evacuating a building. The Grenfell disaster exemplifies how occupants behaviour can be affected by their interpretation of the evacuation instructions received when they are in a situation of interpreting such instructions without any 'expert' or authoritative input (such as they may rely on when being 'marshalled' out of a work environment) within their own homes that contain items of both financial and emotional value (LeGood, 2017). A further consideration is one that some may regard as being 'sensitive' (a possibility that may explain the relative lack of data and research in this area) is the nature of occupancy in multi-storey buildings typical of large UK cities. Whilst it is fully acknowledged that relevant and reliable data is scarce, fires such as that at Grenfell Tower have raised awareness of the possible extent of cultural diversity present in such buildings (Bulman, 2017). Therefore, the aim of this research is to explore perspectives on human behaviour during a fire evacuation of a multi-storey residential buildings in the UK.

Fire safety in multi-storey buildings

High rise buildings are complex and therefore require extensive fire safety measures to be incorporated when designing the building. Heffelmire (2016) states that a key challenge for providing fire safety in a multi-storey building is ensuring that all fire safety systems such as alarms, smoke control and egress systems can sufficiently work together in an integrated system manner. Bengtsson *et al* (2008) agrees that the consequences of any failure of a building's fire-related technical systems and the time of the fire service's response both become more critical in multi-storey buildings. As such buildings have tended to become ever-taller the challenges presented to both the fire service (such as insufficient reach of fire ladders – in 2017 the longest reach 'ladder' in the UK (the Ariel Ladder Platform) had a reach of 42m; 25m shorter than the height of Grenfell Tower) and their occupants also increase.

Cowlard *et al* (2013) suggests that implementing a performance based design for each multi-storey building allows a rational approach to both life safety and property protection objectives. Identification of specific goals, objectives and performance requirements will allow an engineer the scope to demonstrate achievement of a required performance. When providing fire safety requirements for multi-storey buildings, it is vital to ensure a thorough study has been undertaken (Edgar and Chow, 2011). Moreover, when designing a multi-storey building in the UK, the structure must adhere to certain regulations and standards to ensure safe design and construction of the building. The current regulations in the UK are Approved Document B of the Building Regulations 2010 which defines a tall building as any with a top floor height of 45 metres or more. These documents provide legal guidance on fire safety such as stairway widths, ventilation, fire doors and escape routes. Before 2005, fire safety was covered by circa seventy pieces of legislation such as the Fire Precautions Act 1961. It was decided that the numerous forms of legislation should be simplified, thus leading to the creation of the Regulatory Reform (Fire Safety) Order 2005 (Firesafe.org.uk, 2011). For multi-storey residential properties, the Housing Act 2004 must also be adhered to.

The World Trade Centre (WTC) events of September 11th 2001 led to a concern for occupants when evacuating a multi-storey building; the event provided a trigger to reconsider the use of lifts (elevators) for evacuation (Proulx, 2004). Noordermeer (2010) agrees that the events of September 11th 2001 acted as a catalyst to discuss the implementation of lifts in more depth.

The use of lifts for evacuation in high rise buildings can reduce evacuation times from 2-3 hours to 15-30 minutes (Siikonen and Hakonen, 2002). Older, existing lifts were not designed for use in fire situations and consequently the standard instruction to occupants was that, if a fire should occur, they should use the stairs, not the lifts, as an egress route (Haitao, Leilei and Juizi, 2012). However, with the improvement of lift performance it is now becoming feasible to use this technology as a means of evacuation. Nonetheless, Klote *et al* (1992) suggests that designing and constructing suitable lifts for evacuation is, in effect, only 50% of the job; occupants of the building must also be prepared to use the lifts in order to ensure a reduced evacuation time. It should be noted that there are numerous definitions for a variety of ‘tall’ buildings, ranging from multi-storey to mega-tall (Designing Buildings, 2017) and that these may differ between countries. In this research the term multi-storey is used as a generic descriptor of any building that is one storey or greater in height (so as not to exclude the occupants of any specific height (storeys) of building). However, it is accepted that, in the UK, the general expectation would be that the majority of multi-storey buildings would be described as being in the 1-9 storey group, although there is no data in the literature that conclusively evidences this. In addition, the 'normal' expectation of a number of storeys within which the majority of tall buildings would sit varies from country to country. A recent analysis of new tall building construction in London, for example, found that the majority of such buildings were in the 20-29 storey category (Hearn, 2015). London can also be shown to contain at least 618 buildings of 10 storeys or greater, whereas New York has at least 6,080 such buildings (Skyscraperpage, 2017). Given that many may regard New York as the spiritual home of the skyscraper, it may be surprising that the median number of floors for such buildings is a relatively low 16 (Hickey, 2014).

Human behaviour during a fire evacuation

Although adequate fire safety systems are used in most buildings today, fire can still occur; during the period 2009-2013, there were an average of 14,500 fires, 40 deaths and 520 injuries per year in US multi-storey buildings (Ahrens, 2016). Proulx (2001) suggests that such deaths and injuries largely result from incorrect assumptions with regards to the fire-related behaviour of the occupants of such buildings. In the context of an overall fire situation (typically consider to comprise three phases: Phase 1 – period between a fire starting and being detected; Phase 2 – period between occupants being aware of a fire and their making the decision to leave the building; Phase 3 – period between the evacuation commencing and the full evacuation of a building. This should not be confused with the concept of a phased evacuation as considered by Adler (2017)).

A study of 225 multi-storey occupants showed that 93.33% of those surveyed believed that there would be panic during a fire situation (Cordeiro *et al*, 2011), a figure which rose to 96% within the subset of the sample who had actually experienced such a fire. Lo *et al* (2000), however suggest that panic is a misconception and research has shown that, during the initial stages of a fire, occupants behave in a controlled and rational manor. This theory is supported by Proulx (2001) who explains that there is little evidence of panic in actual fire situations. In addition, Winerman (2004) argues that 'panic' is simply not the most appropriate description for the feeling that occupants report experiencing – they are fearful; a state of mind that can result in some unexpected behaviours, such as trying to exit by whatever route they entered the building, If greater attention was given to human behaviour during a fire, then many unexpected behaviours could be eradicated. Once occupants have heard the alarm, seconds or minutes can pass before they begin evacuating (Proulx, 2003).

One of the arguably more unexpected behaviours that has been identified is that people will tend to try and help each other (altruism), particularly when they are familiar to each other. The altruistic aspect of evacuation behaviours has been known about for some time (the Social Categorisation Theory (Tajfel and Turner, 1979) and the Social Identity Model (Reicher, 1987) of crowd behaviour, for example, identified not only altruism but also self-sacrifice) and yet the expectation of panic remains a common belief. This belief appears, at least in part, to be an outcome of overly-exaggerated reporting by media that seem unable to differentiate between fear and panic (Galea, 2012).

Human behaviour during a fire evacuation of a multi-storey residential building differs from that of an occupant in a commercial multi-storey building, due to the form of construction used in each case. People will react when they perceive a fire cue such as smell, noise from other occupants, sight of flames or smoke, or a fire alarm (Kuligowski, 2009). As residential occupants will generally live in fire-tight units, they are unlikely to perceive cues that would be available to commercial occupants (in a typical open-plan office space) such as smell, sight or noise from other occupants who are already aware of a fire; occupants need to be informed of the fire before they can react (Lo *et al* 2000).

Galea (2014) proposes that research into the evacuation during the World Trade Centre attacks of 2011 showed that the occupants did not have adequate information when evacuating the building. For example, the occupants evacuating the World Trade Centre would have not been specifically informed to follow the directions provided by emergency signage; only 38% of occupants evacuating 'see' the emergency signs when evacuating, but 100% of the occupants will follow the signs if they see them, thereby suggesting that emergency signage is not sufficiently effective in securing occupants' attention. This problem may simply be that, as Johnson (2005) argues, occupants will ignore emergency signage and instead retrace the route in which they entered the building. The decision to use a familiar route rather than follow the signs and take an unfamiliar (and therefore presenting an unknown level of uncertainty) path is a feature that occurs often that leads to many accidents. This has, in turn, led to an increasingly sophisticated approach to the incorporation of risk perception (RP) models in connection with seeking to more fully understand the decision-making behaviour of occupants during a fire situation. Kinateder *et al* (2015), for example, suggest that RP is essentially the personalisation of risk within a specific event context, and is a process that, as with most human processes, is subject to cognitive biases and emotions. If such a RP model is accepted it may provide insights into the 'value' of familiarity (as a cognitive bias?) within the decision-making process; commercial building occupants are (in many countries) legally required to engage in regular fire evacuation drills (thereby 'creating' a familiar exit path regarding which they have minimal uncertainty), whereas private multi-storey building occupants are typically only exposed to evacuation signage (rather than becoming familiar with an evacuation route).

Traditionally it is assumed that lifts should not be used as a method of evacuation. However, increasingly this idea has been discarded due to the need for faster and more efficient (than the traditional stairwell routes) forms of evacuation (Ronchi and Nilsson, 2013). To sufficiently design a lift system for evacuation use, designers must possess an understanding of the occupant's behaviour when using the lifts; a common assumption is that occupants will wait indefinitely for a lift to arrive, which in fact does not truly reflect the behaviour of people in that situation (Heyes, 2009). In addition, fire engineers often assume that if lifts are available to occupants and they are made aware that they are safe to use, then they will use them. However, a survey of 424 people by Galea (2014) showed that even if occupants were well informed and the lifts were safe to use in a fire situation, only 33% of people would consider using them. This finding may represent a behavioural change from the findings of an earlier study by Canter (1996), who surveyed a sample of 77 people who had been involved in a fire evacuation where lifts were available for evacuation – 85% people used them. As previously mentioned, however, decision-making in a fire situation is a complex interaction between cognitive biases, personal emotions, quality of information available, and familiarity that arguably results in varying perceptions of risk, and therefore varying decisions regarding evacuation behaviour.

Heyes (2009) proposes that the main concerns occupants have for not using lifts to evacuate a building are:

- Being trapped in the lift if the power fails;
- Concern that smoke or fire may enter the lift;
- The possibility that the lift could fail causing the lift to fall,

- The time it takes to wait for the lift.

Hall (2010) agrees with the waiting time concern, suggesting that remaining stationary while waiting for the lift can easily agitate many occupants (again, fear, rather than panic). Moreover, the probability that an occupant could reduce the evacuation time by waiting for a lift, rather than immediately using the stairs, largely depends on the floor that the occupant is on; the higher the floor, the more probable the evacuation time will be shorter when using a lift travelling at a typical speed. A 2009 guidance document for the Department for Communities and Local Government (DCLG) compared typical speeds for stairwell and lift evacuation routes, and found that, as the evacuation starting point moved up the building, the lift provided an increasingly faster evacuation than use of the stairwell, even when the larger 'carrying' capacity of the stairwell (along with other factors) was taken into account (Charters, Fraser-Mitchell, 2009). Even though such information is known to fire engineers, the information provided to occupants is typically minimal (Hall, 2010). Galea (2014) conducted a survey of which 424 participants were asked about the amount of time they were willing to wait for a lift during an evacuation, the majority of people survey specified a finite time that they would be willing to wait, depending on the floor height, crowd density and the expected (not the calculated, as per Charters and Fraser-Mitchell (2009), for example) waiting time.

Proulx *et al* (2009) suggests that several factors can influence whether an occupant uses a lift for building evacuation, varying from person to person depending on the occupant's knowledge of the egress routes and previous experiences of evacuations. Research has shown that most decisions are based on what the occupant estimates (typically as a non-expert, therefore the validity of such an estimate can be regarded as low) is that fastest route to evacuate the building. A method of increasing the efficiency of an evacuation is by displaying the estimated evacuation of both the stairs and lifts. This will allow the occupants to make an informed decision.

Methodology

To achieve the research aim both quantitative and qualitative methods were used, and both interviews and questionnaires were utilised to collect data for the research, with both adopting an essentially semi-structured approach. This allowed for a more comparative approach to the analysis of the data / information gathered than would be the case with an interview or questionnaire only methodology. In addition, an expert evaluation exercise with respect to the initial questionnaire design (informed by relevant literature) was carried out as a means of establishing if any questions needed to be edited/removed or added. Both the interview and questionnaire designs are discussed in more detail in the following sections.

Questionnaire design

Following research into questionnaire techniques and design the researchers decided on a questionnaire design comprising both open and closed questions in the manner of Fridolf and Nilsson (2012), who combined closed and open approaches within a single instrument when studying fire safety in underground rail transportation systems. The questionnaire also included a section that the participants could use to comment on anything regarding the research. A total of 72 people completed the questionnaire, the participants were occupants of multi-storey buildings, and were constituted as samples of individuals that had or had not been involved in a real fire evacuation situation, thereby representing two data sets to facilitate comparison. By comparing the two situations, an insight can be gained into fire situation behaviours of individuals who have experienced an evacuation, and therefore 'know' how they will react, as opposed to individuals who have not had that experience and therefore believe how they will react.

The questionnaire and interview were designed so as to provide insights, from both the expert and non-expert perspectives, on key issues identified within the literature. These issues can be summarised as covering five areas:

- Challenges facing evacuees during a fire situation;
- Quantity of information provided to evacuees;
- Extent of occupant reluctance to evacuate immediately;
- Factors affecting occupant decision-making during an evacuation;
- Extent of evacuee reluctance to use lifts, even after being informed it is safe to do so.

The questionnaire was designed to be completed as an online survey thereby allowing a large number of participants to complete the questionnaire, whereas the interview was intended to be undertaken by a small number (three) of experts from different countries.

Prior to releasing the questionnaire it was evaluated by relevant experts in the field of the subject, so as to ensure the validity of the questions before being released to survey participants. The evaluation identified some questions as difficult to understand and therefore in need of simplification to ensure the relevance of any answers. In addition, some questions required a small degree of re-wording, and it was suggested that the total number of questions needed to be reduced. A final suggestion was that some question response categories should be changed so as to facilitate analysis of the answers. All of these actions were implemented to ensure the final questionnaire was clear and able to supply more relevant results.

Interview design

The interview method was intended to complement the questionnaire in that it focused on gathering the expertise of fire engineering experts, while the questionnaire focused on non-experts (the occupants). As stated previously, the questionnaire was intended to be as available as possible to non-experts, so as to collect a large data set. The interview, however, took the opposite approach in that it was completed by three experts. In this context, there is a need to acknowledge the debate concerning the relative 'value' of expert and non-expert knowledge. Rae and Alexander (no date), for example, note that, when safety-related risk is the focus, "… the opinions of experts are given greater weight than the opinions of non-experts." By obtaining the responses of both experts and non-experts with regard to a number of specific issues this research aimed to determine the extent of any difference in terms of knowledge (where knowledge (applied information) is considered to be the combination of data (measurements) and information (data given meaning) (Paunović, 2008)) about those issues.

Arguably the key aspect of value applicable to this research is that experts and non-experts (novices) learn differently from what appears to be essentially the same experience. In a multi-storey building fire situation, individuals can be assumed to base their decision-making on their existing knowledge – do not use the lifts, for example; an expert may well have appropriate knowledge to recognise a 'safe' lift, whereas a non-expert may rely on their knowledge of having been instructed that lifts should not be used during a fire situation. In each case, the behavioural outcome would differ. However, the expert typically has the luxury of making a behavioural decision whilst accessing relevant data and information (knowledge) in a safe environment. In comparison, the non-expert sample within this research were expected to evidence relatively little knowledge (in terms of equivalency to the experts) and also be affected by the immediacy (in terms of both their environment and the perception of a possible threat) of the required decision. Weber and Chapman (2005), for example, investigated the possibility of a relationship between the time available to make a decision and the level of certainty/uncertainty about that decision; does delaying a decision (such as when to leave a dwelling and commence evacuation) create uncertainty?

Yin (2009), Kumar (2014) and Saunders (2015) concur and postulate that a semi-structured interview to be the most efficient method of interview through the use of focused questions. Several question were recognised as possible to be answered by a simple ‘yes’ or ‘no’ (such as: Are occupants provided with sufficient information on evacuation procedures?), although the expectation was that the probability of this happening was low. However, the interviewer used such questions in combination with the scope to probe the (expert) interviewee for more in-depth knowledge in the event that their answer was no more than a ‘yes’ or ‘no’. The interviews were designed consisting of five focused questions, with three fire engineering experts invited to participate as interviewees.

Data analysis

The questionnaire findings are presented as a series of graphs showing the occupants responses. Where appropriate, the responses were analysed using the Relative Importance Index formula (Figure 1), as created using Microsoft Excel.

Insert Figure 1 here.

With n5 = highly concerned, n4 = slightly concerned, n3 = neutral, n2 = not really concerned and n1 = not at all concerned. The occupants’ answers were inputted into Microsoft Excel and were checked thoroughly to ensure no inputting errors had occurred. The interviews were conducted through an online audio conversation, and subsequently transcribed in readiness for the application of the content analysis technique.

Results, analysis and discussion

The purpose of this study was to explore human behaviour during a multi-storey residential fire evacuation situation, the decisions occupants make during such a situation, and their choice of egress methods. The data and information gathered from the questionnaire responses and interviews was then analysed in accordance with the methodology discussed previously. The process of distributing (online) the questionnaire and then collecting data and information from the responses took approximately 2 weeks. As part of this process it was determined that the questionnaire typically took approximately 10 minutes to complete, and that a total of seventy-eight questionnaires were completed.

Questionnaire results

Q1. Established the age bracket of each participant, and the building floor on which they resided. Figure 2 shows the results of the age brackets of participants; the majority of respondents were between the ages of 25-34.

Insert figure 2 here.

Figure 3 displays the floor of the building on which the occupants lived; 62.82% of occupants resided between floors 1-9. The results also evidenced that there were 0% of respondents living on floors 50 or above.

Insert Figure 3 here.

Q3. Asked if the participant had previously been involved in a real-life fire evacuation situation while living in a multi-storey building; 30.77% of respondents confirmed they had been involved in a real fire evacuation situation. This could affect the occupants' decision, as it would reasonably be expected that occupants with previous experience of fire evacuation may make different decisions to those that have not. Moreover, Cordeiro *et al* (2011) surveyed 225 people and asked the occupants that had been previously involved in a fire evacuation situation if their reactions would be the same (if they were faced with a further fire evacuation situation) and 54% answered affirmatively.

Q4. Investigated the decisions that participants make during an emergency evacuation of a multi-storey residential building. Figure 4 shows what method of evacuation occupants would choose during a fire evacuation:

i) 66.7% would definitely take the stairs and 16.67% would probably take the stairs;
ii) 7.69% would probably take the lift and 0% would definitely take the lift.

Similar results were produced in a survey undertaken by Galea (2014) of 424 people, of which two thirds said that they would not consider using a lift to evacuate despite being informed that the lifts were a safe and acceptable option. These results show that most occupants are still reluctant to use a lift as a method of egress during an emergency evacuation, and that the stairs would be more than likely used by most occupants. Occupants need to be educated more on the using a lift for evacuation, as in most cases signage alone is not enough.

Insert Figure 4 here.

Figure 5 shows that the higher the floor of residence the more its occupants are likely to use the lift:

i) 0% of occupants on floors 1-9 and 10-19 answered that they would 'Definitely' or 'Probably' take the lift;

ii) 30% of occupants on floors 20-29 answered that they would 'Probably' use the lift;

iii) 42.86% of occupants on floors 30-39 would 'Probably' use the lift.

The data shows that occupants residing in higher floors are more likely to use a lift in an evacuation situation. These results compare well to data collected by Heyes (2009) of 229 respondents, the analysis of which showed a similar linear relationship between floor level and the percentage of respondents that would use the lift as a method of evacuation.

Insert Figure 5 here.

The results shown in Figure 6 show the comparison of selected method of egress and the age of occupants. This illustrates that the older the occupants, the less likely they are to use the stairs to evacuate during a fire situation. This decision would most likely be down to the physical capabilities of older occupants, which would lead to evacuation being difficult and time consuming. While there is no specific evidence within the responses, there may also be some awareness of the tiring nature of walking down multiple flights of stairs. The concerns of evacuation of elderly or impaired occupants was mentioned by one participant of the survey, the participant went on to explain their previous experience of evacuating occupants requiring assistance, in which it was found such an evacuation can take a long time. Furthermore, the results show that 0% of occupants in the 18-24 and 25-34 age brackets would take a lift during a fire evacuation. This suggests that younger occupants take the stairs regardless of what floor they reside on.

Insert Figure 6 here.

Q5. Sought to establish what the participants initial reaction would be to a fire alarm in the middle of the night. Figure 7 shows the results of this question.

These results show that only 21.79% of respondents would evacuate immediately, a result that correlates to a study in Egypt of 62 multi-storey residents who were asked 'what you do when you hear the fire alarm'. The results showed that evacuating the building immediately had a relative important index of 62.39% (Gerges *et al*, 2017). The results here show that there are issues in trying to get occupants to immediately evacuate multi-storey residential buildings. Moreover, Gerges *et al* (2017) showed that the number one ranked factor of occupants was to 'Ask neighbours regarding if there is a fire (i.e. Investigate)', this factor had a relative important index of 84.33%. This coincides with the 41.03% of participants in this research that answered that their initial reaction would be to wait until they were sure of a real fire. Research of 225 participants by Cordeiro *et al* (2011) showed that 65% of occupants first reaction to a fire alarm was 'find out what was happening'. These results show that occupants need to be confident of a real threat before they will immediately evacuate the building.

Insert Figure 7 here.

Q12 Asked the occupants 'If there was an alternate alarm in place that went off when there was a fire within (close) proximity, would this increase the speed of your evacuation?' The results are displayed in Figure 8.

Insert Figure 8 here.

Figure 8 shows that 73.08% of occupants would definitely or probably evacuate quicker. When the response of those occupants presented in Figure 7 that did not answer 'evacuate immediately', it can be shown (Figure 9) that an alternate alarm would either definitely or probably increase 75.44% of occupants' evacuation speed. However, 11.48% probably would not evacuate quicker and 13.12% answered that it would not make a difference to their evacuation speed, thereby evidencing that some people will always be reluctant to leave their residential properties immediately. Nonetheless, the results show that most occupants would actually evacuate quicker with an alternate alarm, if that alarm would make the occupants aware that the fire was a serious threat and not a fire drill. This in turn would improve the evacuation speed for the majority of occupants. This point was highlighted by responder who stated that different alarms in relation to differing proximities of a fire would help the evacuation process.

Insert Figure 9 here.

Q6 Establishes if a resident would use a lift as a method of egress during a fire evacuation situation. Only 1.28% of occupants would 'strongly agree' that they would use a lift. Moreover, 46.15% of participants answered that they 'strongly disagree'. Overall, the results show a clear indication of occupants' reluctance to use a lift during a fire evacuation.

Q9. Asked the occupants if they would use stairs as a method of egress during a fire evacuation. In this aspect, the results were as were expected, based on the literature; 66.67% 'Strongly agree' and 23.08% 'Agree' that they would use the stairs during a fire evacuation. Only 5.13% of occupants answered 'Disagree', which is most likely down to a disability or being physically incapable of using the stairs.

Q10. To ensure an efficient evacuation of a multi-storey building it is vital to give occupants a sufficient amount of information regarding the fire evacuation procedures within their building. This section of the research investigated whether occupants considered themselves to be well informed on the fire evacuation procedures in their buildings. The results are displayed in Figure 10.

Insert Figure 10 here.

Figure 10 shows that 46.16% of occupants 'Strongly agree' or 'Agree' that they are well informed regarding fire evacuation procedures in their building. Moreover, 23.08% 'Disagree' and 11.54% 'Strongly disagree' that they are well informed on their fire evacuation procedures; a worrying statistic, as a lack of information can have a major impact on the success of an evacuation should a real fire occur. Three participants of the questionnaire commented that no evacuation details were provided regarding their multi-storey residential building. However, these results present a more positive picture than does the research completed by Lo, Lam and Yuen (2000) of two cases in Hong Kong, which showed that a total 68.9% of occupants had not received any training on evacuation procedures. Additionally, Cordeiro *et al* (2011) asked 225 occupants in Portugal about their knowledge of evacuation plans, and only 35% answered that they were aware of their building's evacuation plan. These results show that occupants need to be more educated/informed regarding their building's relevant fire safety and evacuation procedures.

If clear information is given to occupants then they will be aware of the most efficient method of evacuation, thereby mitigating some of the various factors can affect how an occupant evacuates.

Within question 11the occupants were asked which factors would most likely affect their decision making when choosing a method of egress during a fire evacuation. Figure 11 shows the occupants' responses:

- The main factors that occupants base their choice of egress method on is 'The emergency evacuation signs' (37.18%) and 'the familiarity of the route' (35.90%).
- The least common choice is 'The route that requires the least amount of physical work'; only 1.28% of occupants chose this factor which could be due to issues displayed in previous results that some occupants may have a disability or physical incapability.
- Only 7.69% of occupants answered that 'the least congested route of egress' was a factor that can affect their choice of egress method.

These results could indicate that other occupants will continue to evacuate using an egress method that is highly congested despite other options being available. Research by Lawson (2011) asked participants to rate how influential different factors were on their choice of egress, with the factors being rated from 1 (not at all influential) to 5 (very influential). The results showed that occupants rated 'other occupants' as the most influential factor with an average rating of 5, followed by 'distance' and 'instruction from authority figure' with an average rating of 4. The 'familiarity with route' only measured a 3.5 on the influence scale, although Figure 10 shows that this same factor was chosen as the main factor affecting the occupant's choice of egress. One participant of the questionnaire commented that the use of technology in fire evacuation should be implemented to aid occupants; the researchers here believes that this would be a viable option due to the high number of smart phones being used within the UK.

Insert Figure 11 here.

The last section of the questionnaire asks the occupants to rate their concerns for different hazards relating to lifts and stairs during a fire evacuation situation, the results for the lift hazards can be shown in Table 1.

Hazard	**Relative**	**Rank**

	Importance Index	
Being stuck in the lift	89.60%	1
Smoke entering the lift	88.95%	2
Fire entering the lift	84.53%	3
Power failure leading to the lift falling	80.53%	4
Having to wait to long for the lift to arrive	76.05%	5
Other people needing to use the lift more than me	71.84%	6
Not being provided with enough information on using the lift during a fire evacuation	70.53%	7

Table 1 Respondents answers to 'if using a lift to evacuate a multi-storey building during a fire evacuation, how concerned would you be about the following hazards?'

Analysis of Table 1 shows that the main concern when using a lift during a fire evacuation was 'being stuck in the lift' (89.60%) followed by 'smoke entering the lift' (88.95%). This shows that more information could be given to the occupants regarding the engineering of the lift and its actual level of resistance to fire and smoke. For comparison, Table 2 displays the results of the occupants' concerns regarding hazards when using the stairs during a fire evacuation. These results show that 'fire entering the stairway' (86.87%) and 'smoke entering the stairway' (82.56%) are the greatest concerns of occupants when evacuating using the stairs. This data shows that occupants are worried that a stairway could be filled with fire or smoke. A sufficient way to address this hazard would be to install 'smart' signs that tell the occupants which egress stairway to take to avoid the fire.

Hazard	Relative Importance Index	Rank
Fire entering the stairway	86.67%	1
Smoke entering the stairway	82.56%	2
Stairs taking too long to evacuate	73.25%	3
Congestion in the stairway	69.74%	4
Slipping or falling down the stairs	66.12%	5
Not being physically capable of walking down stairs	56.86%	6
Not being familiar with the route	54.12%	7

Table 2 Respondents answers to 'if using stairs to evacuate a multi-storey building during a fire evacuation, how concerned would you be about the following hazards?'

Moreover 'not being physically capable of walking down stairs' (56.86%) ranked number 6 on the table. Heyes (2009) research (focused on San Francisco) showed that 55% of occupants answered 'not at all concerned' about not being physically fit enough to travel down many flights of stairs. The researchers suspect that some occupants who state they are not concerned about being physically fit enough to walk down a high number of stairs, may assume they are in better physical condition that they actually are.

Interview results

Three interviews were completed with experts within the field of fire engineering, one from the UK, one from New Zealand, and one from Sweden. Each participant was invited to take part in a 20 – 30 minute interview which consisted of five questions. One interview was conducted face-to-face, and the other two were conducted via an online call.

The first question asked the interviewee's opinion on the main challenges that occupants face during a fire evacuation of a multi-storey residential building. Interviewee 1 suggested that the main challenge is occupants not having enough information during the evacuation process. Interviewee 2 agreed that providing information on evacuating the building is one of the main challenges when evacuating a multi-storey residential building. Furthermore, interviewee 3 explained that the long distances occupants need to travel to evacuate high-rise buildings in particular is the main challenge, especially if there are occupants with mobility impairments or disabilities. Interviewees 1 and 3 both mentioned 'culture', as this can affect occupants' decisions when evacuating a multi-storey residential building, with Interviewee 1 suggesting that people in the Middle East are not as serious about fire alarms as people within the UK.

The second question of the interview investigated whether occupants are provided with enough information on the fire evacuation procedures within multi-storey residential buildings. Interviewee 2 and 3 both explained that this depends on the country of the building but the consensus was that information and awareness could be improved within the UK. Interviewee 1 suggested that there is a lack of use of technology during fire evacuations, and that smart phones, for example, could be utilised to improve evacuation efficiency. Furthermore, Interviewee 1 stated that information given by other occupants during a fire evacuation can be inaccurate and during a previous fire evacuation of a multi-storey building a voice communication message stated, "Please evacuate the building immediately" but there was no information given regarding the shortest and safest route to take.

Question three aimed to find out if occupants are reluctant to leave their properties unless they are confident of a real threat. All three interviewees agreed that occupants were reluctant to leave their properties with both Interviewee 1 and 2 using the words 'definitely'. Interviewee 2 and 3 both argued that the evacuation time from a residential building is higher than that for an office building. All three interviewees suggested that occupants are reluctant to leave their belongings, or will collect them before they evacuate a multi-storey residential building. Interviewee 1 also suggested that occupants tend to look at others as leaders before they evacuate, and their decisions on when to evacuate will be based on their knowledge of fire situations and any previous fire/evacuation experience.

Question four asked what the main factors are that affect occupants' decisions during an evacuation. Interviewees 2 and 3 both identified 'social' interaction or influence as being a key factor; the information occupants receive from other occupants can impact their decisions. Moreover, Interviewee 1 suggested that the structural layout of the building is a main factor, as it plays an important role on what evacuation route the occupants may take. This point is supported by Interviewee 2 who stated that the environmental condition of the building is critical to finding a way out. Smoke was mentioned by both Interviewees 1 and 2 as important factors than can affect the decision of the occupants; the sight or smell of smoke can change the occupants egress route. Interviewee 2 suggested that the physical performance of the occupant also needs to be considered, especially in terms of mobility, because if the occupant is required to use many stairs to evacuate then their body's physical performance becomes a factor.

The interviewees were asked in question five to explain if they thought occupants were still reluctant to use lifts during a fire evacuation, even if they are deemed safe to use. All three interviewees agreed that many occupants still have the stereotypical view that lifts should not be used, no matter what. Interviewee 2 suggested that this can also depend on the time an occupant is willing to wait for a lift; previous research has shown that, in general, occupants are not willing to wait more than 10 minutes for a lift. Interviewee 1 agreed that waiting too long for the lift to arrive can deter occupants from using a lift. Interviewee 1 also suggested that their personal experience has led to the conclusion that some occupants would not use the lift even if it was safe, due to factors such as:

- Not being enough room in the lift for the whole family,
- Too many other occupants waiting for the lift,
- Some lifts being out of order, which gave the impression that the lifts were unreliable.

Interviewees 2 and 3 stated that occupants need to be more educated about both fire situation and evacuation procedures, and given more information on the use of lifts during an evacuation of a multi-storey residential building.

Conclusions

The aim of the research was to explore human behaviour during a fire evacuation and place such behavioural responses in the context of a multi-storey residential building in the UK so as to suggest factors relevant to the safe evacuation of residents. The research evidenced that there are various factors that discourage occupants from using certain egress routes. For example, the results of the questionnaire evidenced that fire and smoke entering the stairway are the main factors that affect use of the stairs during an evacuation. In addition, the questionnaire results evidenced that the factors deterring occupants from using a lift are concerns of being stuck in the lift and smoke or fire entering the lift. The interviews also concluded that lifts are still perceived as being dangerous to use during a fire evacuation situation, which is no longer completely accurate as some lifts in multi-storey buildings are designed to allow safe evacuation during a fire. However, occupants need to be thoroughly educated and clearly informed with regard to such factors.

Various issues can affect the occupants' behaviour during a multi-storey fire evacuation. The questionnaire results showed that the majority of occupants would not immediately evacuate their residence when hearing a fire alarm. Moreover, the results of the interviews stated that this is because occupants are reluctant to leave their personal possessions or property as in many cases the fire alarm is a false alarm or a drill. The results of the questionnaire also showed that the occupant's reluctance to evacuate immediately once hearing a fire alarm could be reduced through the use of an alternate alarm that indicated a fire was within close proximity. The researchers conclude that this would help occupants to make more effective decisions in a fire situation and thus speed up the evacuation time of those occupants in closest proximity to the fire.

There are several factors to consider that can affect occupants' receipt of 'threat' cues during a fire evacuation. The literature review identified that occupants of residential multi-storey buildings may not receive cues such as smell, sight and noise, as they generally live in fire-tight properties. The questionnaire results show that most occupants will wait until they are sure a fire is 'real' before they evacuate, thereby suggesting that cues such as other people evacuating are not considered until a real fire has been confirmed. The interviews produced results that identified culture as an important factor affecting the interpretation of the cues occupants receive; some cultures are not serious about fire alarms and will not consider an alarm as evidence of a 'real' fire situation. Occupants fire responses should be considered to be an important factor to be cogniscent of when drawing up evacuation strategies / plans for multi-storey buildings.

Recommendations for future research

The researchers acknowledge a constraint when carrying out this research was their limited access to fire engineering experts within the UK. Additional interviews with experts within the UK would undoubtedly add further insight into human behaviour of occupants specifically in the UK.

The research suggests that a further questionnaire could be distributed to occupants that reside in properties having a lift that can be used during a fire evacuation. This will produce detailed results on whether occupants would not use a lift even after being informed that the lift is safe to use. Due to the limited information provided to occupants during the evacuation, the researchers recommend further research is required into this area.

The results of the research have shown that occupants need to be more informed on the fire safety procedures within their building, the research would suggest a possible mobile phone application that could be used by occupants of a building. The app would update occupants on any changes to the building, such as lifts being out of use, and could be used during a fire evacuation to inform occupants of the safest route to take, ensuring the shortest evacuation time. The researchers also recommend an alternate alarm within a multi-storey building that alerts occupants when there is a fire within close proximity. This would speed up the evacuation decision for those occupants who would usually wait until they were sure of a real fire before evacuating. The researchers believe that the implementation of these recommendations would improve both the level of safety and the speed of a fire evacuation in the context of a multi-storey residential building.

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Figures

$$= \frac{5(n5)+4(n4)+3(n3)+2(n2)+n1}{5(n1+n2+n3+n4+n5)}\ x\ 100$$

Figure 1 Relative Importance Index (%)

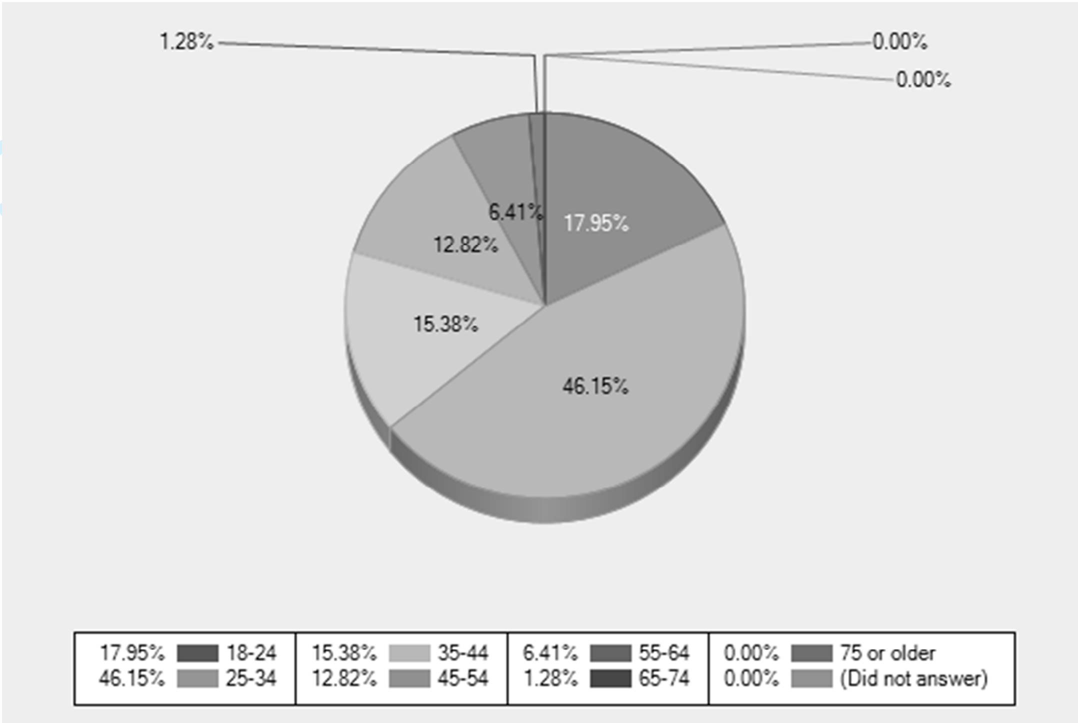

Figure 2 Age of participants

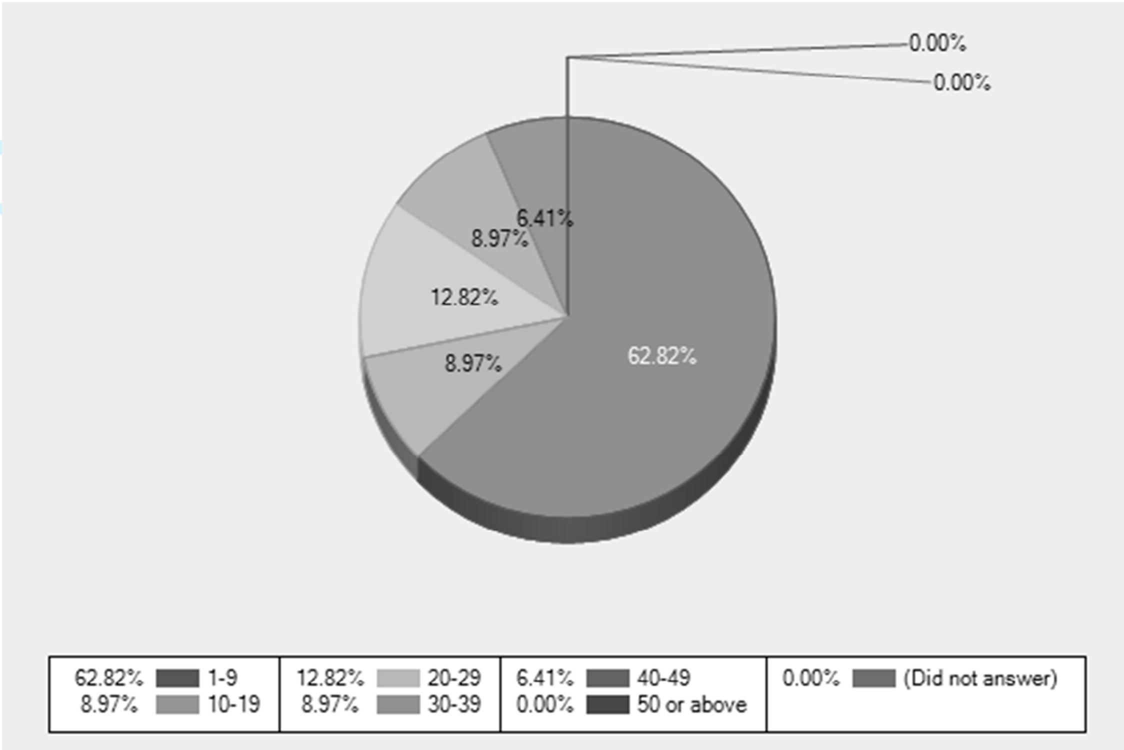

Figure 3 Floor of building that occupants reside

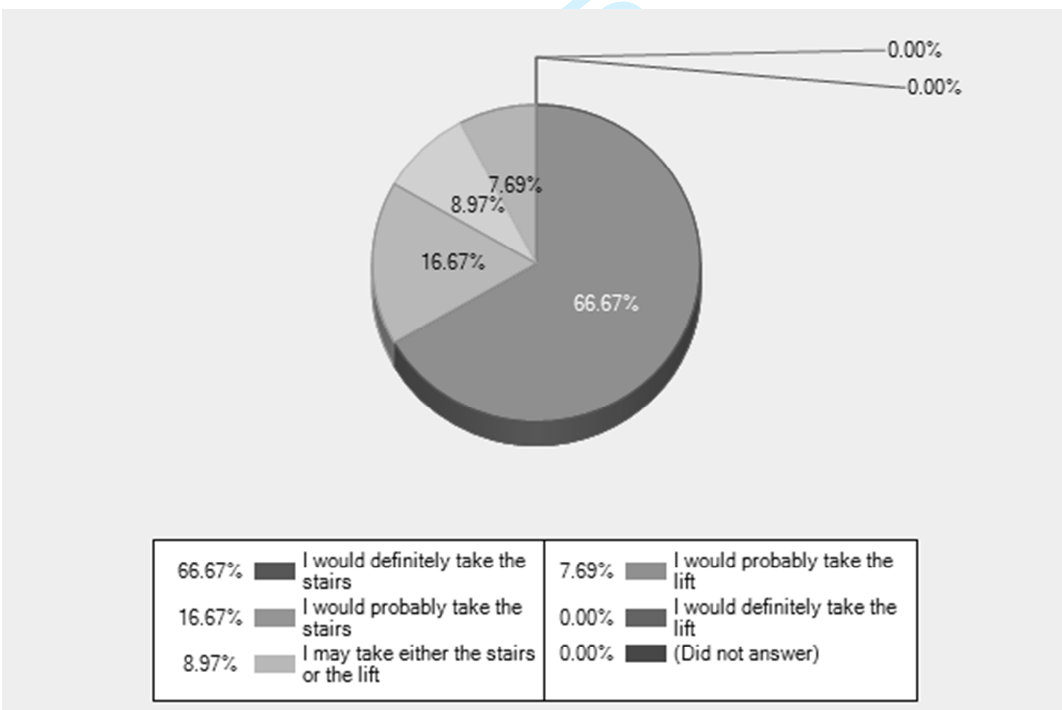

Figure 4 Methods of evacuation

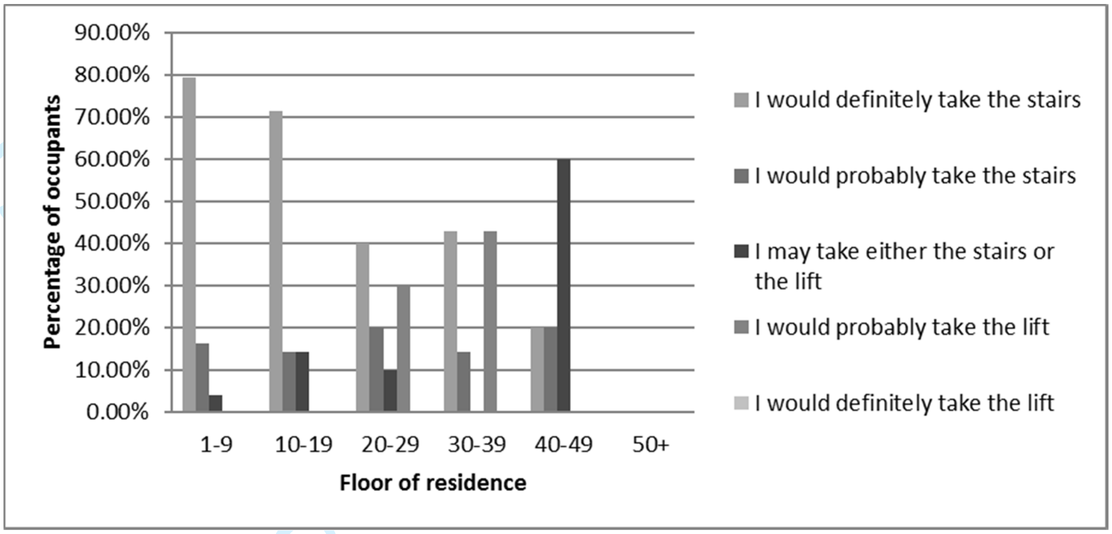

Figure 5 Comparison of egress method and floor of residence

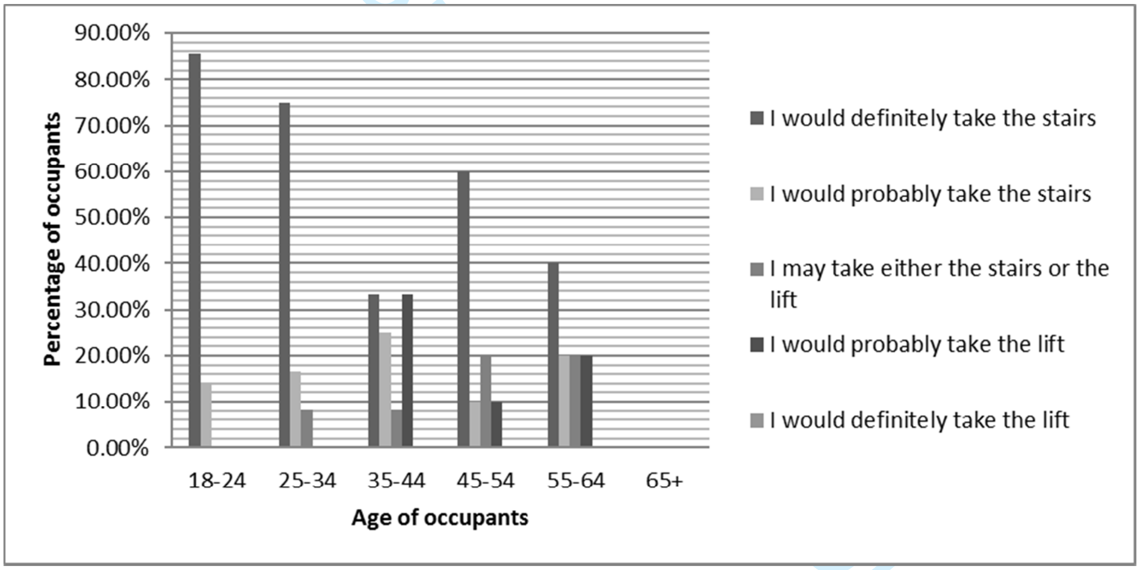

Figure 6 Choice of egress and age of occupant comparison

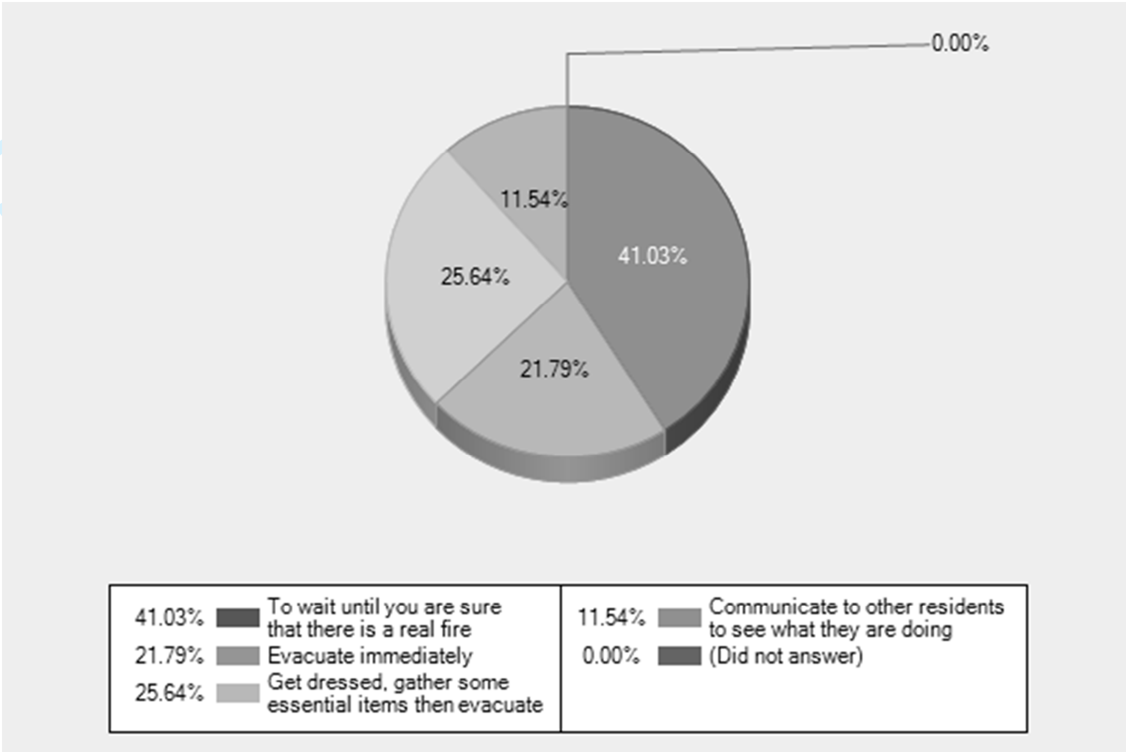

Figure 7 Initial reactions to a fire alarm in the middle of the night

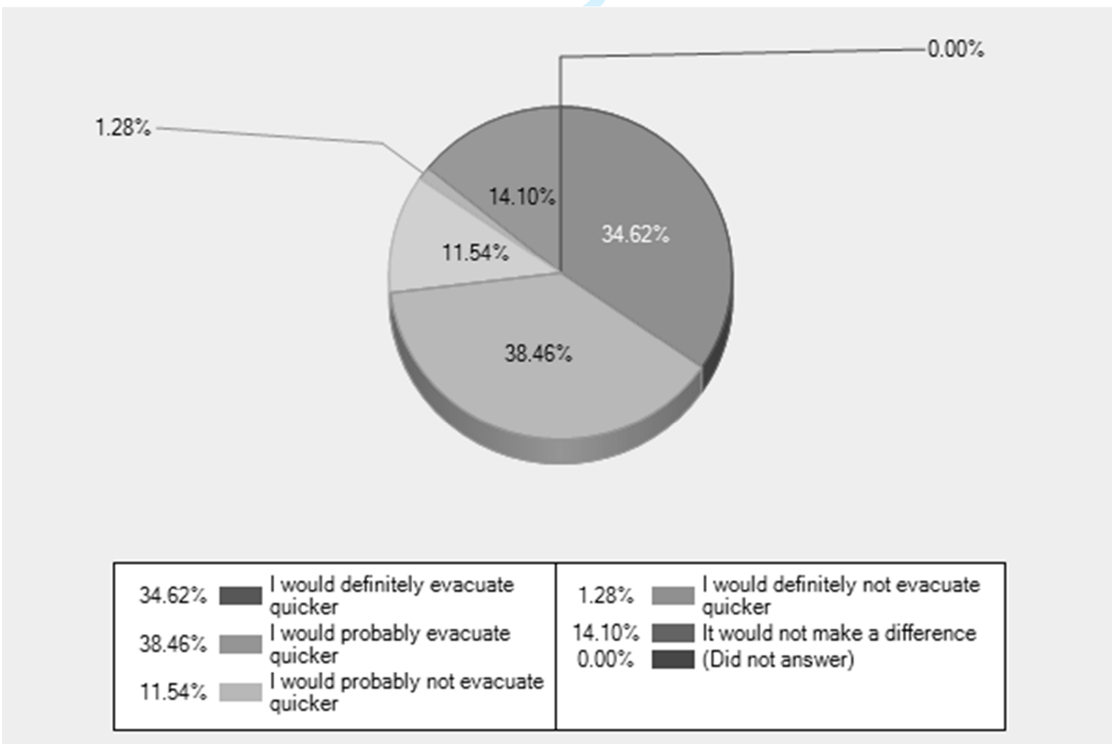

Figure 8 Results of evacuation speed if an alternate alarm was in place

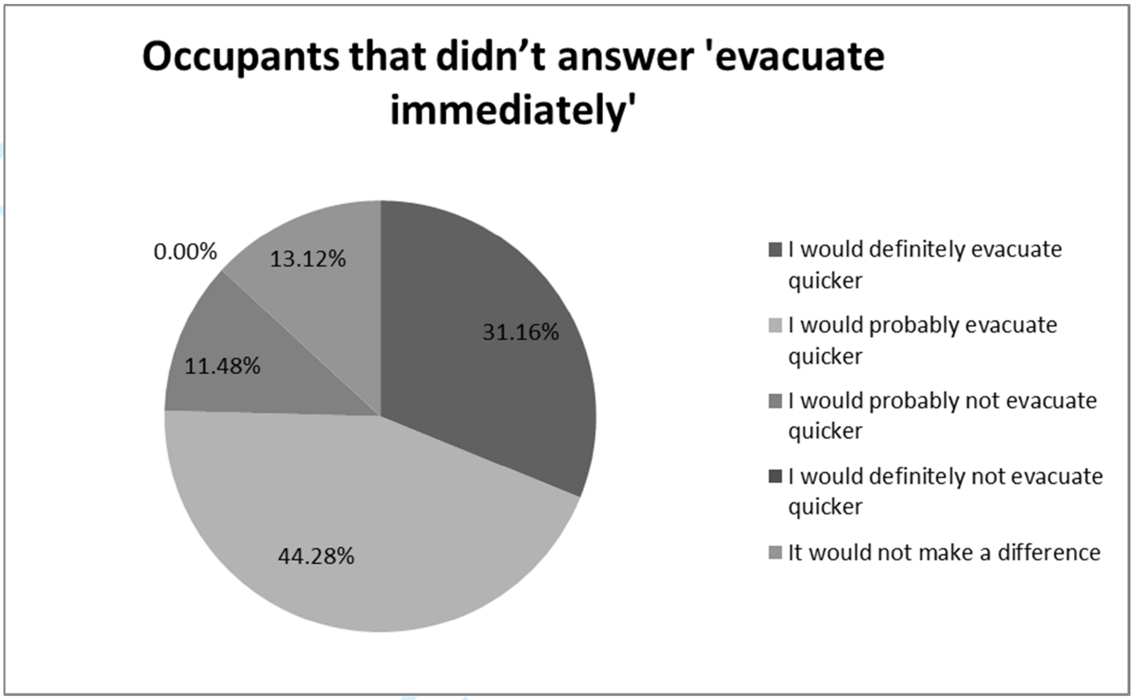

Figure 9 Would an alternate alarm make a difference to occupants' evacuation speed?

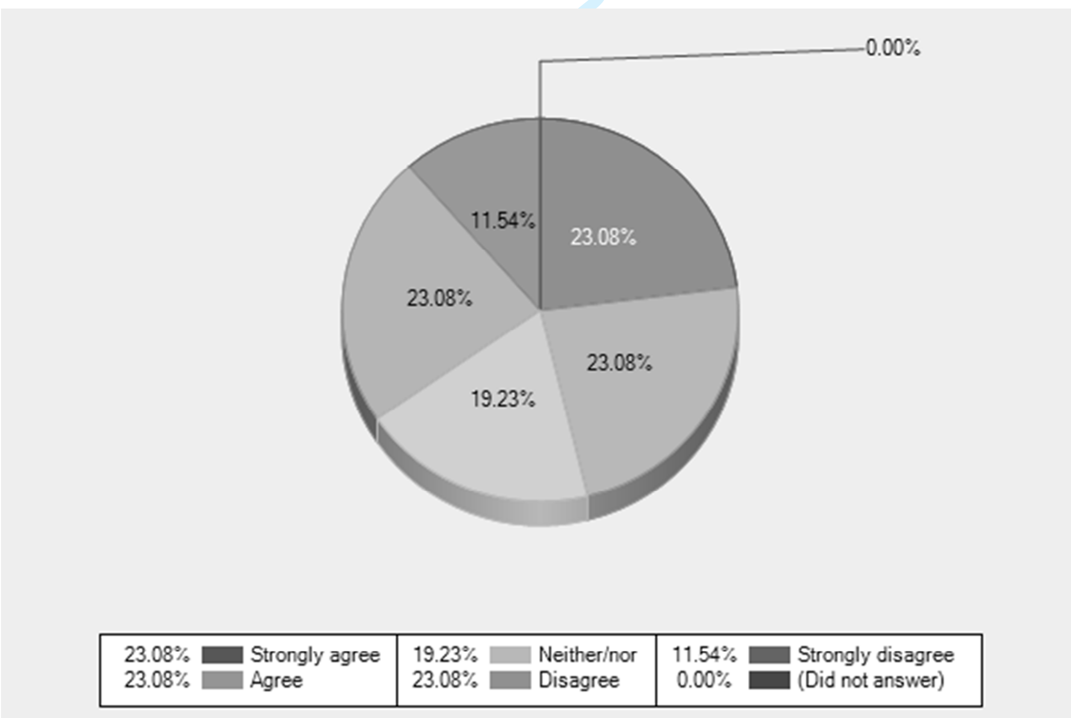

Figure 10 Occupants are well informed on the fire evacuation procedures within their building

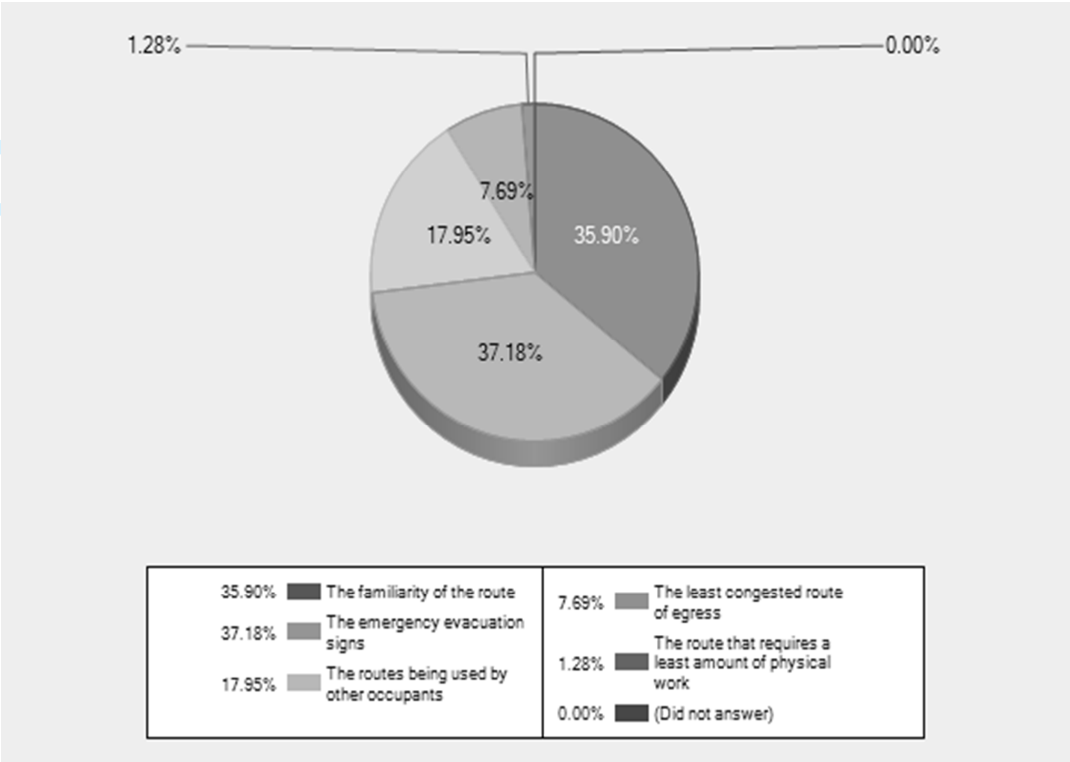

Figure 11 Factors affecting occupant's choice of egress method