

## **Suitability of Escape Route Design for Elderly Residents of Public Multi-storey Residential Building**

**Nurul Liyana Hanapi<sup>1</sup>, Sabarinah Sh Ahmad<sup>1\*</sup>, Norhati Ibrahim<sup>1</sup>,  
Azli abd Razak<sup>2</sup> and Nor Merlisa Ali<sup>2</sup>**

<sup>1</sup>*Centre of Studies in Architecture, Faculty of Architecture, Planning & Surveying, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.*

<sup>2</sup>*Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

### **ABSTRACT**

The rapid increase in the number of multi-storey residential buildings has raised concerns on the provision of escape route design. Statistics from the Fire and Rescue Department Malaysia showed a high number of casualties involved elderlies when there is a fire. This paper studies expert opinions on the suitability of escape route design for elderlies in public multi-storey residential buildings based on the Uniform Building By-Law (UBBL) 1984 specifications. The result showed enhancing the escape route design suited for the elderly is needed arising from the slow walking speed of the elderlies which can cause delays in the evacuation process. The majority of experts agreed that the escape route design is most important to provide safe evacuation process followed with occupant physiological and psychological characteristics.

*Keywords:* Elderly, escape route design, evacuation, safety

### **INTRODUCTION**

#### **Population Growth and Safety of the Elderly**

The rapid increase in the urban population has led to an expansion in the number of multi-storey residential buildings. The government has provided high-rise low-cost housing to meet the housing needs of the low-income group and to reduce the number of illegal residents and squatter settlements

#### **ARTICLE INFO**

*Article history:*

Received: 15 September 2016

Accepted: 30 December 2016

*E-mail addresses:*

liyana513123@gmail.com (Nurul Liyana Hanapi),  
sabar643@salam.uitm.edu.my (Sabarinah Sh Ahmad),  
norhati@salam.uitm.edu.my (Norhati Ibrahim),  
azlirazak@salam.uitm.edu.my (Azli Abd Razak),  
merlisa@salam.uitm.edu.my (Nor Merlisa Ali)

\* Corresponding author

(Karim, 2012; Muhamad Ariff & Davies, 2009). Malaysia has a specific uniform building by-law and planning guideline for public housing in Malaysia which has been developed by the Malaysian Construction Industry with the aim of ensuring the safety of the building occupant (Husin et al., 2012). Despite this, public safety issues continued to be reported (Husin et al., 2012).

Although building design is considered as the main factor in ensuring safety studies have shown that the response and behaviour of the people are often based on psychological and physiological factors (Hofinger, Zinke, & Künzer, 2014; Tan, Hu, & Lin, 2015; Tancogne-Dejean & Laclémence, 2016). During an emergency human impulsive behaviour and panic attacks are the main causes of casualties. Furthermore, the deterioration of environmental condition triggered new adaptive behaviours and physical responses (Ha & Lykotrafitis, 2012; Kady & Davis, 2009). There are many factors that influence the decision making and age is one of them (Zhan et al., 2013).

The number of those aged above 60 is expected to increase by 56% between 2015 and 2030 (UN Population Division, 2013). The increment of elderly population increases the concern for their safety, especially in the low-cost housing residences. During evacuation, this group of people could reduce or affect evacuation efficiency especially in staircases.

## **Expert Opinion in Safe Escape Route Design**

The involvement of experts from different backgrounds is needed to ensure maximum safety in residential buildings. The basic principles of designing for fire safety in a building remain the same and is set by the Malaysian UBBL guidelines. Examples of the building regulations set for the public multi-storey residential building are maximum travel distance, provision of a fire hydrant and hose reel, alternative exit, and number of staircases.

Although due consideration has been given to aspects related to fire safety in buildings. Regular maintenance is needed to ensure all the fire safety facilities are well equipped and in good working condition and protected from vandalism.

The Fire Department is not only involved in an emergency situation but also during the design process stage to ensure adherence to fire safety regulations. Elevators too have been found suitable for evacuation purposes. Nevertheless, important fire safety factors such as the design and occupancy load of staircases, the maximum distance, and other matters related to staircases need to be prioritised in a multi-storey building.

## **METHODS**

The approach of this study is to discuss expert opinions on the reliability of escape route designs for elderly residents in public multi-storey residential buildings. The

experts consisted of architects, engineers, fire brigade officers and building controllers. A pilot study was conducted to check the reliability of the survey questionnaire. Sixteen respondents were gathered and based on their responses, the Cronbach's Alpha (based on standardizing items) shows a 0.733 which fall under the acceptable internal consistency of range.

One hundred survey forms were distributed via email and only 27 experts responded. A quantitative method using a close-ended questionnaire survey consisting of three sections was used to ascertain the demographic background of the respondents, expert opinion regarding the safety measure, and a five-point Likert scale, ranging from "not important at all" to "very important". Each question is analysed according to the independent means score which ranged from high to low as shown in Table 1.

Table 1  
*Mean score range*

| Mean score range | Description |
|------------------|-------------|
| 4.1 < Mean < 5.0 | High        |
| 3.1 < Mean < 4.0 | Medium      |
| 2.1 < Mean < 3.0 | Average     |
| 1.1 < Mean < 2.0 | Low         |

## RESULTS AND DISCUSSION

### Respondents' Profile

There were 27 expert respondents involved in this survey consisting of architects (48%), fire brigade officers (36%), engineers (8%), building controllers (4%) and

academics (4%). In terms of fire safety design in buildings, 48% of the participants were found to have more than 10 years' experience; 32% had between one and two years of experience, 3-5 years' experience (16%) and 5-10 years' experience (4%). More than two thirds of the respondents were from the public sector (68%) with experience in designing public multi-storey residential buildings and 32% from the private sector with similar experience.

### Safety for the Elderly

The second section of the survey involved a survey on experts view regarding safety measures in public multi-storey residential building. There are six variables in this section. The score of the survey is shown in Table 2 based on the highest to the lowest agreement of the survey.

Almost all (91.7%) experts agreed on the need to enhance building safety regulation enhancement. The majority (87.5%) of experts agreed that due to the slower walking speed of the elderlies compared with the younger groups, the efficiency of the evacuation process will be affected. Although during the emergency situation the usage of lift is prohibited 83.3% of the experts thought that the lift could be beneficial to transport people to safety. Slightly more than half or 56.5% of the experts considered current fire regulation to be adequate to ensure maximum safety while 43.5 % disagreed, raising issues whether existing fire regulation is adequate to ensure maximum safety for the aged.

Table 2  
*Safety measure of building occupied by elderlies*

| Variables  | Yes  | No   |
|--|------|------|
|  | %    |      |
| With the increment in elderly occupants, the building safety regulation needs to be enhanced                       | 91.7 | 8.3  |
| Low walking speed delayed and affected the evacuation efficiency   | 87.5 | 12.5 |
| Lift usage is advisable for the elderlies as they are more prone to the risk of falling during emergency situation | 83.3 | 16.7 |
| Travel distance plays a very important role in determining the total evacuation process.                           | 78.3 | 21.7 |
| Elderlies need longer time to evacuate   | 75   | 25   |
| The current fire regulation is enough to ensure maximum safety for the elderly                                     | 56.5 | 43.5 |

### Fire Safety Measurement

The third section of the questionnaire was conducted using a Likert scale where comparisons of means were used to determine which variables are more important. Ranking is based on the high and medium score where high priority is when the means score 4 and above, scores below

4 will be considered as a medium priority.

Results of questions in Section 3 is shown in Table 3. Everyone responsible for providing safety measure in the building falls under the high priority. The top three people responsible are the firefighters (4.7778) followed by building maintenance officers (2.6296) and building designers

Table 3  
*Priority for responsibility, and factors affecting evacuation and causes of fire*

| Priority | Responsibility               |               | Factor                      |               | Cause of fire          |               |
|----------|------------------------------|---------------|-----------------------------|---------------|------------------------|---------------|
|          | Variable                     | Means Ranking | Variable                    | Means Ranking | Variable               | Means Ranking |
| high     | Firefighter                  | 4.7778        | Maintenance                 | 4.2963        | Short circuit          | 4.2593        |
|          | Building maintenance officer | 4.6296        | No. of Occupancy            | 4.1111        | Home appliance failure | 4.2593        |
|          | Building designer            | 4.4815        | Passive & active            | 4.0370        | Explosion              | 4.0000        |
|          | Building owner               | 4.4444        | Design layout               | 4.0000        |                        |               |
|          | Regulatory body              | 4.1852        |                             |               |                        |               |
| medium   |                              |               | State of mind               | 3.8889        | Open flame             | 4.2593        |
|          |                              |               | Building layout familiarity | 3.8519        | Glowing fire           | 4.2593        |
|          |                              |               | Experience                  | 3.5926        | Hot surface material   | 4.0000        |
|          |                              |               | Ages                        | 3.5185        |                        |               |

(4.4815). Firefighters scored the highest followed by building maintenance officers and building designers. As for the factors that affect the evacuation efficiency, regular maintenance, the level of density, fire safety criteria available and also the complexity of the building layout feature as a high priority while panicking, and familiarity with the building layout counted as medium priority. The third question is the cause of fire, where the experts and the statistics from the fire rescue department Malaysia agreed that

the short circuit is the main cause of fire breakout in residential area.

Table 4 shows the result of occupants response to an emergency and majority of experts found awareness to be a high priority. On the subject of end-user safety factor it was found that the presence of too many safety locks had a mean value of 4.2593 suggesting that it could delay or block evacuation. Second highest is the lack of emergency training.

Table 4  
*Occupants' response towards reducing injury and end-user safety factor*

| Priority | Occupant response                               |               | End-user safety factor                      |               |
|----------|---|---------------|---|---------------|
|          | Variable  | Means Ranking | Variable                                    | Means Ranking |
| high     | Aware of the exit passage                       | 4.4074        | Too many safety locks                       | 4.2593        |
|          | Attended a fire drill training                  | 4.2963        | Lack of emergency training                  | 4.0000        |
|          | Aware of the location of safe assembly          | 4.2222        |   |               |
|          | Aware of the location of firefighting equipment | 4.1852        |   |               |
|          | Attempt to put down the fire                    | 3.9259        | Concern of valuable item                    | 3.9259        |
|          | Evacuate early                                  | 3.8519        | Too many obstacles in corridors             | 3.7-27        |
| Medium   | Have knowledge in using firefighting equipment  | 3.5556        | Not aware of the safety means and equipment | 3.6296        |
|          | Have an experience involving fire               | 3.5185        |   |               |

Table 5 shows the building element and escape route design that should be incorporated in the public multi-storey residential building to ensure maximum safety during the evacuation process. It is clearly shown that high priorities are the variables that are stated in the UBBL 1984 as part of the regulation for the multi-storey residential. The provision for sufficient exit doors to cater to the elderly in residential

building was the highest priority, as the experts deemed that it would contribute positively to the overall evacuation process.

Future research could test design features to check whether they contribute towards improving the evacuation process. The width and depth of the staircases fall under the medium category as it does not contribute much to the evacuation efficiency. Alternative staircases have often

Table 5  
*Building element and escape route design*

| Item | Variable   | Means  | Overall ranking from respondent |          |
|------|--|--------|---------------------------------|----------|
|      |  |        | Ranking                         | Priority |
| 1    | Sufficient number of exit doors                        | 4.4444 | 1                               |          |
| 2    | Staircase width maintained                             | 4.3704 | 2                               |          |
| 3    | Corridor follows max travel distance                   | 4.1481 | 3                               |          |
| 4    | Provide alternative staircase                          | 4.1111 | 4                               |          |
| 5    | Provide alternative exit                               |        |                                 | high     |
| 6    | Uniform tread and riser                                |        |                                 |          |
| 7    | Exit width sufficient with building capacity           | 4.0370 | 5                               |          |
| 8    | Provide both handrails                                 | 3.9259 | 6                               | medium   |
| 9    | Bigger passage to cater to the elderly                 | 3.8889 | 7                               |          |
| 10   | Occupant load control                                  | 3.7778 | 8                               |          |
| 11   | Width of staircase is less than the depth of staircase | 3.5556 | 9                               |          |
| 12   | Protected corridors                                    | 2.4444 | 10                              |          |

been provided however proper maintenance is needed to ensure evacuation efficiency. That is why the staircases' width are to be maintained throughout the building and alternative staircases fall under the highest priorities.

### CONCLUSION

The increase in the urban and elderly population gives rise to challenges in the time taken to evacuate the public from multi-storey residential buildings. A survey conducted to solicit expert opinions on the matter found the need to enhance evacuation efficiency. There was some disagreement on the issue whether current regulations are sufficient to deal with the matter. Further study is needed to test on the suitability of building regulation towards the occupant

density and elderly occupant as there is still a lack of study on the minority of the population.

The results showed the end user or human factor is important in providing safety during emergency human factors such as the presence of excessive numbers of safety locks and absence of emergency training could delay the evacuation process.

### ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Ministry of Education in providing a Mybrain15 scholarship award. Additional funding was provided by the Malaysian Ministry of Higher Education under the Fundamental Research Grant Scheme 600-RMI/FRGS 5/3 (87/2015) for publication.

## REFERENCES

- Abbas, M. Y., & Saruwono, M. (2012). Our 'Golden' Citizens with 'Golden' Facilities?. *Procedia-Social and Behavioral Sciences*, 49, 127-146. doi:10.1016/j.sbspro.2012.07.012
- Benson, W. F. (2002). CDC 's Disaster Planning Goal : Protect Vulnerable Older Adults. [Media contact]. Washington, DC: CDC Healthy Aging Program.
- Ha, V., & Lykotrafitis, G. (2012). Agent-based modeling of a multi-room multi-floor building emergency evacuation. *Physica A: Statistical Mechanics and Its Applications*, 391(8), 2740–2751. doi:10.1016/j.physa.2011.12.034
- Hofinger, G., Zinke, R., & Künzer, L. (2014). Human Factors in Evacuation Simulation, Planning, and Guidance. *Transportation Research Procedia*, 2, 603–611. doi:10.1016/j.trpro.2014.09.101
- Huang, L., Chen, T., & Yuan, H. (2014). Simulation Study of Evacuation in High-rise Buildings. *Transportation Research Procedia*, 2, 518–523. doi:10.1016/j.trpro.2014.09.069
- Huo, F., Song, W., Chen, L., Liu, C., & Liew, K. M. (2016). Experimental study on characteristics of pedestrian evacuation on stairs in a high-rise building. *Safety Science*, 86, 165–173. doi:10.1016/j.ssci.2016.02.025
- Husin, H. N., Nawawi, A. H., Ismail, F., & Khalil, N. (2012). Preliminary Survey of Integrated Safety Elements into Post Occupancy Evaluation for Malaysia's Low Cost Housing. *Procedia - Social and Behavioral Sciences*, 36, 583–590. doi:10.1016/j.sbspro.2012.03.064
- Kabeshova, A., Launay, C. P., Gromov, V. A., Fantino, B., Levinoff, E. J., Allali, G., & Beauchet, O. (2016). Falling in the elderly: Do statistical models matter for performance criteria of fall prediction? Results from two large population-based studies. *European Journal of Internal Medicine*, 27, 48–56. doi:10.1016/j.ejim.2015.11.019
- Kady, R. a., & Davis, J. (2009). The effect of occupant characteristics on crawling speed in evacuation. *Fire Safety Journal*, 44, 451–457. doi:10.1016/j.firesaf.2008.09.010
- Karim, H. A. (2012). Low Cost Housing Environment: Compromising Quality of Life? *Procedia - Social and Behavioral Sciences*, 35, 44–53. doi:10.1016/j.sbspro.2012.02.061
- Kuligowski, E., Peacock, R., Wiess, E., & Hoskins, B. (2013). Stair evacuation of older adults and people with mobility impairments. *Fire Safety Journal*, 62, 230–237. doi:10.1016/j.firesaf.2013.09.027
- Lo, S. M., Zhao, C. M., Liu, M., & Copping, A. (2008). A simulation model for studying the implementation of performance-based fire safety design in buildings. *Automation in Construction*, 17(7), 852–863. doi:10.1016/j.autcon.2008.02.014
- Mohamed, M. F., Raman, S. N., Iman Pratama, T. M., & Mohammad Yusoff, W. F. (2014). Outdoor Environment of Low-cost Housing: A case study of Flat Taman Desa Sentosa. *E3S Web of Conferences*, 3, 01005. doi:10.1051/e3sconf/20140301005
- Muhamad Ariff, N. R., & Davies, H. (2009). Sustainable Living Environment for Urban Low-Income Households in Malaysia: Key Factors for Maintenance. *Proceedings of the 2009 International Symposium On Construction in Developing Economies : Commonalities among Diversities, CIBW107, 1(2002)*, 380–393.
- Ortman, B. J. M., Velkoff, V. a., & Hogan, H. (2014). An aging nation: The older population in the United States, 1964, 1–28. Retrieved from census.gov
- Simkins, T. E. (2005). *Study on High-rise Evacuation of Elderly Residents during Fire Alarms*, (Unpublished Report), Galesburg Fire Department, Galesburg, Illionis.

- Siu, O.-L. (2012). Engaging Adolescents to Care for Elderly Safety in the Community. *Procedia - Social and Behavioral Sciences*, 38, 7–14. doi:10.1016/j.sbspro.2012.03.318
- Tan, L., Hu, M., & Lin, H. (2015). Agent-based simulation of building evacuation: Combining human behavior with predictable spatial accessibility in a fire emergency. *Information Sciences*, 295, 53–66. doi:10.1016/j.ins.2014.09.029
- Tancogne-Dejean, M., & Laclémence, P. (2016). Fire risk perception and building evacuation by vulnerable persons: Points of view of laypersons, fire victims and experts. *Fire Safety Journal*, 80, 9–19. doi:10.1016/j.firesaf.2015.11.009
- Tibaek, S., Holmestad-Bechmann, N., Pedersen, T. B., Bramming, S. M., & Friis, A. K. (2015). Reference values of maximum walking speed among independent community-dwelling Danish adults aged 60 to 79 years: a cross-sectional study. *Physiotherapy*, 101(2), 135–40. doi:10.1016/j.physio.2014.08.005
- Tuunainen, E., Rasku, J., Jäntti, P., & Pyykkö, I. (2014). Risk factors of falls in community dwelling active elderly. *Auris, Nasus, Larynx*, 41(1), 10–6. doi:10.1016/j.anl.2013.05.002
- UN Population Division. (2013). Population Ageing and Sustainable Development. *Popfacts*, (2014), 1–4. doi:ST/ESA/SER.A/290
- Uniform Building By Law 1984.
- Wuschke, K., Clare, J., & Garis, L. (2013). Temporal and geographic clustering of residential structure fires: A theoretical platform for targeted fire prevention. *Fire Safety Journal*, 62, 3–12. doi:10.1016/j.firesaf.2013.07.003
- Yatim, Y. M. (2009). *Fire safety models for high-rise residential buildings in Malaysia*, (Doctoral dissertation), Heriot-Watt University, United Kingdom.
- Zainal, N. R., Kaur, G., Ahmad, N. 'Aisah, & Khalili, J. M. (2012). Housing Conditions and Quality of Life of the Urban Poor in Malaysia. *Procedia - Social and Behavioral Sciences*, 50, 827–838. doi:10.1016/j.sbspro.2012.08.085
- Zhan, X., Yang, L., Zhu, K., Kong, X., Rao, P., & Zhang, T. (2013). Experimental study of the impact of personality traits on occupant exit choice during building evacuation. *Procedia Engineering*, 62(1), 548–553. doi:10.1016/j.proeng.2013.08.099