

## **Optimum Escape Routes Designs and Specification for High-Rise Buildings.**

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### **ABSTRACT**

In Malaysia, high-rise buildings built for residential purposes are a common phenomenon especially in urban areas. This is due to the high demand for residential flats in town areas, which has motivated private and the Semi-Government Companies to build more high-rise residential buildings. This trend was driven due to the limited land availabilities and the high land value in town area. Due to the number of occupants in high-rise residential buildings, an optimum escape routes specification is essential to be analysed to ensure that every ones in the buildings can safely evacuate the building during fire emergency. It is difficult to change human behaviour but the building specifications can be changed more easily. In this regard, the building element best known as escape route, that is escape stairs, corridors and fire doors, should be designed and constructed to serve the occupants the best they can by not allowing any further delay in the evacuation process. The design and construction of escape routes needs to consider not only the evacuation time but also the construction time, economics, construction method and space utilization factors.

In this paper will be discussed the analysis of optimum escape routes provided in some high-rise building in Kuala Lumpur and Penang. Some important points in design, construction, layout and orientation will be discussed as well. Malaysia Building Regulation will be used as an evaluation tools. Computer simulation SIMULEX is used to evaluate the evacuation process.

**Keywords:** Fire safety, Escape Route, Fire Risk Assessment, Evacuation.

**Article Type:** Case Study, Comparative/Evaluating.

## 1.0 INTRODUCTION

Evacuation from building fire is essential and has to be done as soon as the fire alarm is sounded or fire cues have been detected, the sooner the better because it could save lives. The issue on how safe is safe enough in escape route design and construction is yet to be answered. This is because "to evacuate or not to evacuate" high-rise residential building has been hotly debated in all sectors of the fire protection industry (MacLennan, 2001). According to MacDonald, (1985) and Proulx (2001), non-evacuation or "stay-in-place" procedure is proposed as an appropriate behaviour during high-rise building fires for high-rise residential, hotel and dormitory buildings. But, after the September 11 2001 tragedy, the idea of not evacuating from a high-rise building seems to be inappropriate any more. The theory of buildings being built with fire resistant materials sufficient to withstand fire, so that residents can stay in their own flats or flats of their neighbour until the fire being put out seem to be inappropriate any more. The risk that high rise buildings could completely collapse if fire breaks out as in the World Trade Centre tragedy is still high, especially if it is a steel structure building. However it is not ruled out that a building design with sufficient fire resistance material in place will increase fire safety in buildings as mentioned by the Canadian Wood Council (2000), that fire safety in a building can be achieved through proven building design features intended to minimize the risk of harm to people from fire to the greatest extent possible.

According to Proulx (2001), over the past decades, a number of people have died in the process of evacuation from high-rise buildings during fire and many of them are found in corridors and stairwells which often far away from the site of fire. Especially if there are obstacles in the passageway such as encroached objects from wall, occupant's belonging placed in staircase, etc which will reduce the width of staircase. Therefore, congestion on the staircase due to the bottle-neck's effects occurs. Optimum specifications of escape routes i.e. corridors, fire doors and staircases and the orientation of those elements become necessary to ensure the smooth evacuation of people from the building in fire incidence.

## 2.0 BACKGROUND OF FIRE SAFETY ISSUES IN BUILDINGS

There are hundreds of thousands of fires in buildings, about 400 people will lose their lives, and 14,000 people will suffer injury, most likely from burns or smoke inhalation in United Kingdom annually (Billington, *et. al.* 2002). Ramachandran (1999) says that every year, fires in the UK kill about 800 people and cause non-fatal injuries to 15,000 people. On average per year, the direct material damage is about £1,200 million and the indirect loss is about £120 million. The direct and indirect losses in the UK represent about 0.21 per cent of the gross domestic product (GDP). The average number of people dying in fire in UK has dropped about 50% after three years but the numbers of casualty increased about 7.14%.

In Malaysia, statistics (1990 – 1999) show that 39.78% (9,512 cases) of fires had occurred in residential buildings (Yatim, 2001). The total numbers of fire in the United Kingdom involving dwellings are about 35,000 per year in 1966 (JFRO, 1968) and this statistic have shown the upward trends which increased at about 8% every year till 70's (JFRO, 1970). The upward trends continued where in 1994 the dwelling fires were 66,300. In 1997, dwelling fire cases were 72,200 where around three-quarters of all fires and casualties occur in dwellings. Even though the number of people killed each year in fires in the UK is decreasing, with 1994 the lowest for 30 years, but yet there were still 676 deaths, 475 of which were in their own homes (Home Office, 1996). The reduction in deaths in the UK in the years 1994 has been attributed to the fact that more households have installed smoke alarm (Home Office, 1995). However, the number of death in UK increase again, and an estimated 560 people died in fires in the home and about 14,900 people were injured that a 5% increase on 1996 (HRO, 1998). The death tolls seem to fluctuate after 1996 where estimated number of deaths in accidental dwelling fires in 2001 was 435, compared to 397 in 2000 (ODPM, 2003). Even though the number of deaths were relatively decreased compared to 90's, there were still too many deaths, and something should be done to increase the fire safety aspect, particularly for high-rise residential buildings because the risk of fire in dwelling buildings is greater than other categories of buildings.

This shows that an adequate means of escape in buildings is essential to give people a chance to reach the safe designated place (assembly place) to save their life from fire. Design and construction of the building, particularly escape routes and safe assembly area, needs to be reviewed.

### **2.1 Current practice for security harness**

The current practice whereby many building owners were inspired to harness security measures by putting an iron grill or an extra safety precaution such as double locked iron gates at the main entrance and other exit routes of their property, has increased the risk of being trapped if fire breaks out (Yatim and Harris, 2005). By providing a 'safe route' from the building, the number of injuries in a building fire could be reduced. According to Billington *et al* (2002), "This safe route will be most effective if it follows the normal circulation patterns of the building, since research has shown that when people react to a fire incident they tend to follow the routes with which they are most familiar". Shields and Boyce (2000), have studied the evacuation from a large retail store and among of the findings are that 50.1% have chosen the nearest exit to evacuate from the building and 19.5% choose a familiar exit to evacuate from the building. Therefore, a well-designed means of escape will usually provide an effective circulation pattern for the building and vice versa. Cost and time can be saved if means of escape design principles are followed at the earliest stages of a project. Basic design principle should be considered when designing an escape route, i.e. the positions of exits and entrances, corridor patterns and widths, staircase numbers and locations, and the need for lifts. However, understanding human behaviour in the particular area where the building is going to be erected for the residential purposes is of equal importance, and it will help in smoothing and shaping the decision making process.

### **2.2 People perception about fire in buildings**

Human perception and the actions that they are going to take in an emergency situation, i.e. fire emergency and evacuation process, needs to be studied to enable the design of internal building circulation and escape route e.g. escape stairs, and to model fire safety evacuation. Occupants in high-rise residential buildings are normally attempting to evacuate the building in a building fire, but if the fire and smoke condition is worse and it is not possible to do so, then they may have no choice but to return to their respective apartments, or seek refuge in other apartments, and wait for the fire fighters to rescue them (Yung et. al., 2001). It raises another issue i.e. "To evacuate or not to evacuate" as mention by MacLennan, (2001). The main problem encountered in evacuation processes is when smoke enters into an escape route through a broken fire door and/or through the gaps between the door and floor or the door and door frame. Another problem is traffic congestion during evacuation processes (Yahya, 1999). Evacuation from building fire could be fully successful if occupants have been given early warning about the fire before it becomes uncontrollable. From opinion survey 40.9% occupants of high-rise residential building when asked what they are going to do first if fire alarm went off, they said that they will immediately evacuate from the building and 22.6% said the evacuation is second thing after they have done something else e.g. call 999 or try to put out fire before evacuation. 8.7 % said evacuation is the third thing to do after they have done two other things (Yahya, 2011).

### **3.0 RESEARCH APPROACH AND INVESTIGATION**

There are two approaches in this research i.e.

1. **Building Observation** i.e. to identify the key issues and problems encountered in high-rise residential buildings, to understand and evaluate the building environment related to the evacuation process if people need to evacuate in an emergency situation, and the provision of escape route i.e. corridors, escape stairs, fire door and fire lobby, to know the common design layout. This will lead to the formation of study models for further investigation in lavatory.

2. *Computer Simulation* i.e. SIMULEX, to simulate people evacuating from the then pre-design buildings. The aim is to investigate the optimum design and specification of escape stairs, corridors and fire doors to be used in future high-rise buildings. There are eight differences scenario (Figure 1) of building orientation models has been developed (Table 1 the description of the models) based the outcome from the first methodology and then it has been expanded to the 225 models to test the optimum design and specification.

**Table 1.0:** Model description

Model	Description
1	Opposite directions with fire door.
2	Opposite directions without fire door.
3	L-Shape direction with fire door.
4	Straight direction with fire door.
5	Opposite direction horizontal staircase with fire door.
6	Opposite direction horizontal staircase without fire door.
7	One direction horizontal staircase with fire door.
8	Cluster types with one staircase.



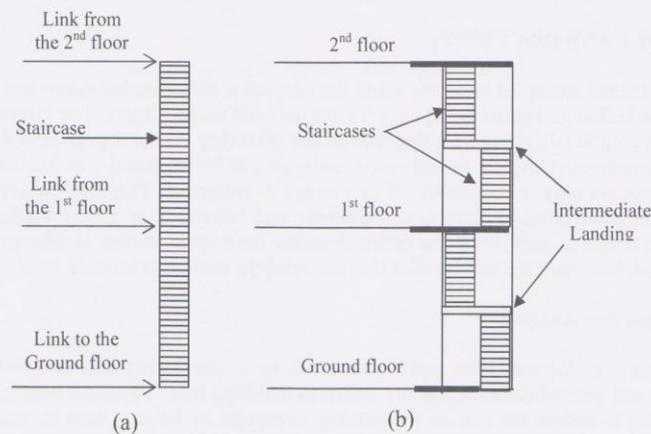
**Figure 1.0:** Study Models

### 3.1 Building Observations

A number of high-rise residential buildings in Kuala Lumpur and Penang have been identified to participate in this study. Kuala Lumpur and Penang were chosen because Kuala Lumpur is a capital of Malaysia and the population in Kuala Lumpur is among the highest to compare with the other city in Malaysia. Penang is a tourist attraction island with high population which has many high-rise residential buildings to cater for the population demands.

### 3.2 Computer Simulation

Models were designed using CAD software and saved in a dxf file. If more than one floor needs to be analysed, dxf files have to be uploaded as many times as desired and the floor then named accordingly. All floors have to be connected to each other by using staircases designed in the SIMULEX environment.



**Figure 2.0:** (a) Staircase without landing floor link to every floor, (b) Staircases with intermediate landing floors connecting the floors.

To determine the number of staircase needed, analysis of the effect of the intermediate landing staircase i.e. landing connecting between two staircases (see diagram in figure 2.0b) on the evacuation time, needs to be carried out. If there is no significant time differences between the two cases, only one staircase will be designed in Simulex linking to each of the floors served by the staircase as in figure 2.0a. The staircase is needed to be linked to the appropriate floor level. The link width must be the same as the door width. After links have been made, an exit or exits need to be assigned to enable the occupants to evacuate the building. The exit assigned is an end destination for the occupants to out the building. People then have to assign in the model before simulation can start. People's characteristics are determined from the choices given in the SIMULEX. These pre-installed people characteristics can be changed later on if needed.

### 3.3 Model Determination

The study models used are based on the analysis of observation data of the existing high-rise residential buildings which was carried out earlier. There are five main components in the study models developed i.e. (i) Room / Chamber, (ii) Corridor, (iii) Staircase, (iv) Fire Door, and (v) People. Figure 3.0 shows the example of people simulated in the study model. Evacuation time is measured after each and every one in the model has safely evacuated the model. Analysis is done by adopting

the philosophy that *Any design which does not cause traffic congestion at any level, and allows people to be smoothly evacuated from the building with the minimum time taken, is the safest.*

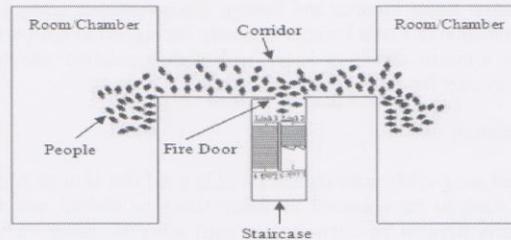


Figure 3.0: People simulated in the study model

#### 4.0 RESULT AND DISCUSSION

There are limited resources to review about the integration of human behaviour and structure design in high-rise buildings. Human beings are very dynamic and unique. It would be “Never Ending Story” if we are trying to talk about what they can do and what they cannot do, etc. In this regard, only the technical constructive evidence of staircase simulation will be discussed. The human perception and characteristics are only being considered in a unique environment. Therefore, the investigation result may be different if the difference characteristics and behaviour of people applied in different ergonomic situations. Analysis of the optimum escape route specifications is referred to the optimum width of corridor, staircase and fire door that permitted the shortest evacuation time.

##### 4.1 Staircase Analysis

Here comes to the important aspect that needs to be considered after analysing the occupants' behaviour and perception about fire safety in buildings that “Technical Solution”, hopefully, it will be able to reduce the risk on the building occupants by helping them in the evacuation process. Technical solution is known as “controllable variable” can offer alternative measures to minimise the gap caused by the lack of knowledge and experience by guiding the occupants to follow the best possible way to evacuate the building if a fire breaks out. In this regard, building elements best known as escape routes which are escape stairs, corridors and fire doors should be designed and constructed to serve the occupants the best it can by not allowing any further delay in the evacuation process. The design and construction of escape routes need to consider not only the evacuation time but also the construction time, economic, construction method and space utilization factors. Parameters considered in this analysis are (1) Evacuation Time, (2) Staircase Width, (3) Corridor Width, (4) Fire Door Width, (5) Occupants Traffic Flows, (6) Escape Staircase Orientation, (7) Number of Occupants, and (8) Final Exit.

There are eight scenarios (see Figure 1.0) all together and they have been developed based on the observation of high-rise residential buildings in Malaysia. The vast majority of high-rise residential buildings observed having emergency staircases either parallel, vertical, or straight with the corridor, or staircase without corridor that served the clustered flats. Those scenarios either come with or without the fire door. The philosophy adopted here is *the faster is the safer*. The purpose of this study is to know at what point is the design of staircase, fire door and corridor in high-rise buildings giving an optimum safe route to be used by occupants. To test the popular assumption that *wider staircase and corridor are better for evacuation process*.

Scenario one in which staircase design was not parallel with the corridor and it is fitted with a fire door. This model is named as “Opposite Direction with Fire Door” (See figure 4a). There are five sizes of staircases with the minimum width is 914 mm and the maximum width is 1524 mm. Every

staircase design with one fire door is analysed by taking the evacuation time of 200 occupants evacuating the model. There are eight difference widths of fire door, ranging from 762 mm (2 ft 6 inch) to 1524 mm (5 ft). Tests have being carried out and figure 3b shows the test result for those models. The test was to determine whether there is any correlation between the staircase size and the fire door size fitted to the staircase compartment. Is there any significant evidence that staircase and fire door designs contributed to the congestion in evacuation processes? To test the popular assumption that *the bigger space provided, the better people evacuated*.

#### 4.2 Model Analysis

Staircase width 914 mm and 1067 mm shows about the same pattern that evacuation time increased when fire door width increased. Fire door size 914mm (3 ft) resulted the longest time taken by all occupants to evacuate the building.

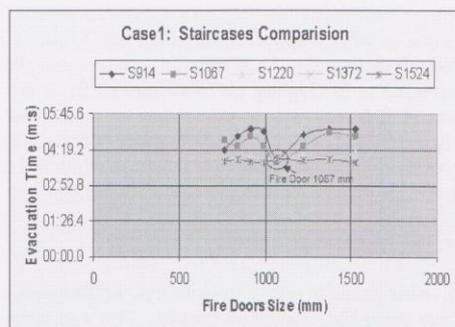
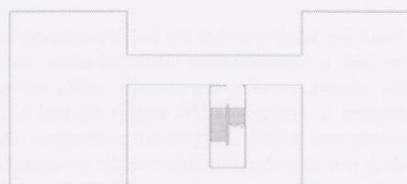


Figure 4 (a): Evacuation Time Vs Fire Door



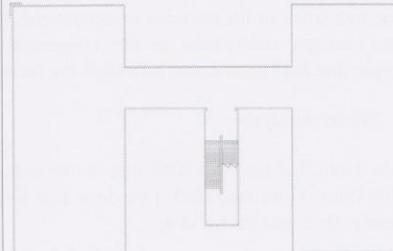
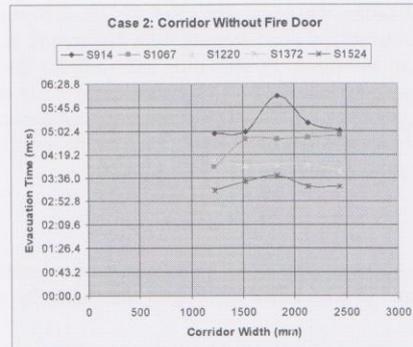
Picture 4 (b): Model 1, Opposite directions with fire door.

The time is slightly improved when door size increased and the best time taken was when the fire door width is 1067mm (3.5 ft).

It is then increased again (figure 4a) when the door size increases to 1220mm (4ft) and 1370 mm (4.5ft) and it remained about the same when the door width was further increased to 1524mm (5ft). It seem like there is significant evidence that traffic is likely congested if staircase width 1067 mm and lower used for the design as in model one. Test result for the staircase width 1220 mm, 1372 mm and 1254 mm do not show any significant change at any fire door width. It is evident that there is no congestion at the staircase which evacuation time is about 3 to 4 minute.

The second test on the model 1 is slightly modified, with no fire door on it, and increasing the corridor width, the result as in Figure 5b. Corridors widths are ranging from 1220 mm (4 ft) to 2440 mm (8 ft) and marked as model 2. Figure 5a shows model 2 designed without fire door.

The result shows that staircases 914 mm and 1067 mm is a significant evidence that congestion is likely to happen because evacuation time for both of the staircase, if corridor width increased, was nearly 5 minute. For the staircase 914 mm shows worse scenario that when all cases were above 5 minute accepts for the corridor width 1220 mm, 4 minute 56.9 second. Irregular phenomenon happened on staircase 914 mm when corridor width was 1828 mm (6 ft) i.e. evacuation time increase quite a lot that 6 minute 6.1 second. Investigation is till going on to identify what has caused this phenomenon. At the beginning, it is seem like congestion at the staircase might has caused this phenomenon but evacuation time is going down when corridor width increase to 2134 mm.



**Figure 5 (a):** Evacuation Time Vs Corridor **Figure 5b:** Opposite directions without fire door

Staircase 1067 mm has the best evacuation time when corridor width 1220 mm (4ft) that 3 minute 56 second. Evacuation time increased when corridor width increased to 1524 mm (5 ft) and remain about the same even after the corridor width further increased to the highest i.e. 2440 mm (8 ft). It is not happen to staircase 1220 mm (4 ft) and 1372 mm (4 ft 6 inch) where evacuation time recorded is steady and it has no significance changes. There is significant evidence to say that the wider corridor does not contribute to improve the evacuation process in high-rise building if staircase width did not increase. The same pattern happen to the model 3, 4, 5, 6, 7 and 8 (See figure 6, 7, 8, 9 and 10).

From the test that has been done, some conclusions can be drawn as follows:

1. A fire door smaller than 914mm (3ft) is not viable to use in high-rise buildings. Traffic jams are likely to happen at the door entrance and can delay the evacuation process. This can be seen from the numbers of people evacuated in the model tested (see figure CS6 compare to picture CS7).
2. There is significant evidence that if the door size is equal to the staircase size, it will improve the evacuation processes. From the test it is found the best evacuation time is when the door and the staircase are at the same size.
3. There is significant evidence to suggest that congestion at staircases will occur if the door width is greater than the staircase size. From figure 1 it shows that time taken remains about the same even after the door size has been increased twice.
4. There is proof that certain fire door sizes fitted to the staircase compartment would contribute to the smooth evacuation process in high-rise residential buildings. It can be seen in figure 1 that times varied when the door size changed. The best door size is 1067 mm (3.5ft) for staircase size 1067 mm (3.5ft).
5. In term of popular assumption *wider staircase and corridor are better for evacuation process*, it can be concluded that the wider staircase is better for the evacuation process, but there should be no bottlenecks in the middle of the escape route. Width corridor does not contribute to the performance of evacuation. The size should be uniform for corridors, doors and staircases. For example if door width is greater than the staircase width, it will not contribute to the smooth flow of people, instead it will cause congestion at the staircase. If the door width is smaller than the staircase width, it will cause traffic congestion at the door entrance. However, the number of occupants is becoming the determining factor; i.e. an excessive number of occupants will increase the time to complete evacuation.

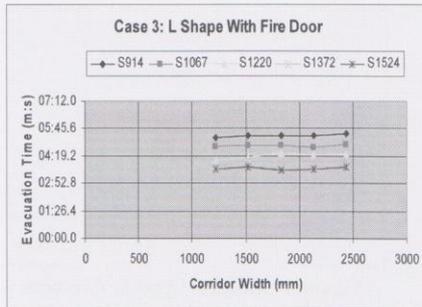


Figure 6a: Evacuation Time Vs Corridor

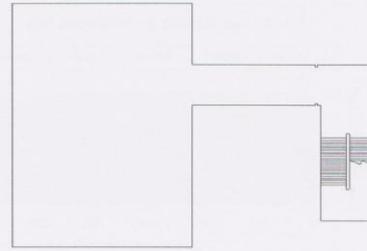


Figure 6b: Model 3: One direction L-Shape with fire door.

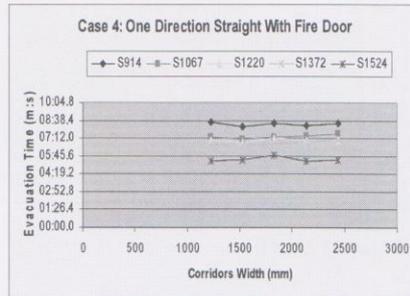


Figure 7a: Evacuation Time Vs Corridor

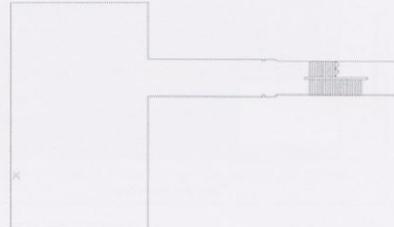


Figure 7b: Model 4: Straight direction straight with fire door.

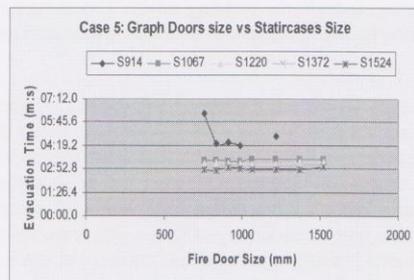


Figure 8a: Evacuation Time Vs Fire Door

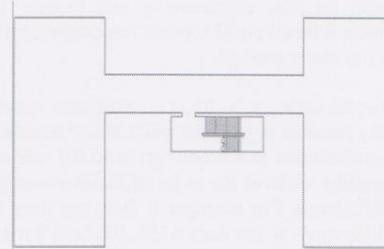


Figure 8b: Model 5: Opposite directions horizontal with fire door.

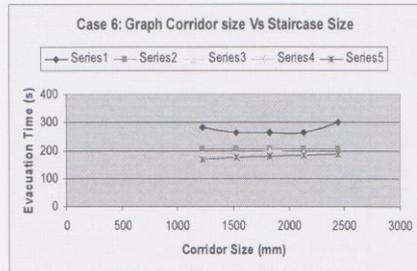


Figure 9a: Evacuation Time Vs Corridor

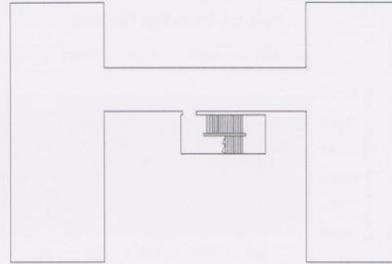


Figure9b: Model 6: Opposite directions horizontal without fire door.

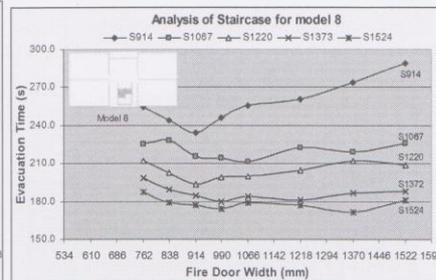
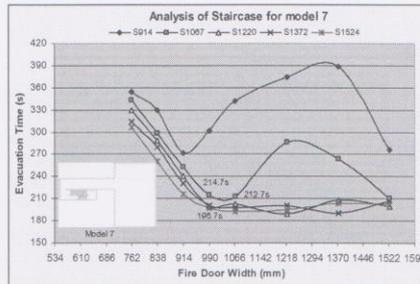


Figure 10: Evacuation time Vs corridor width for model 7 and 8

#### 4.3 Analysis of staircase, fire door and corridor drawn from the study models

Table 1 summarise the staircase, fire door and corridor widths from the models studied. The analysis was made based on the assumption that if the evacuation time recorded fell within 30 seconds, it was considered as being of no significance. Therefore the staircase, fire door and corridor are assumed to offer the same efficiency i.e. able to allow people to evacuate the building safely. The assumption made is based on 30 seconds response time allowance for the occupants to start their evacuation once a fire alarm goes off.

For the optimum width, more staircases recorded within 30 seconds differences of evacuation time on any fire door or corridor width in any models are assumed as an optimum width. Optimum means that consideration is not only given to the minimum evacuation time recorded but at what fire door or corridor width is the most staircases recorded the evacuation time close together within 30 seconds differences. For example if there are three staircases recorded evacuation time within 30 seconds differences at fire door width 1067mm but evacuation time recorded says 180 seconds, even though the minimum evacuation time recorded was 160 second but only confers to one staircase at fire door width says 914mm, therefore fire door width 1067mm considered as the optimum one.

The second analysis is what staircase, fire door and corridor width conform to the majority of the models tested. For example, staircase 1220mm and 1372mm conform to all models, therefore staircase widths 1220mm and 1372mm are considered as an optimum dimension for the staircase. Meanwhile, the optimum fire door width is 990mm, 1067mm and 1220mm, and optimum corridor width is 1220mm and 1524mm. These optimum specifications relate to the specific number of people simulated, i.e. overcrowded situation. For different occupancy levels the optimum specification may be different.

**Table 1:** Optimum specifications suggested resulting from the models studied based on the evacuation time recorded.

Model	Staircase Width (mm)	Fire Door Width (mm)	Corridor Width (mm)
1	1220, 1372, and 1524	914, 990, 1067, 1220	-
2	1220, 1372, and 1524	-	1220, 1524, 1828
3	1220, 1372, and 1524	-	1220, 1524
4	1067, 1220, and 1372	-	1220, 1524, 1828
5	1067, 1220, 1372, and 1524	914, 990, 1067, 1220, 1372, 1524	-
6	1220, 1372, and 1524	-	1220, 1524, 1828, 1232, 2436
7	1220, 1372, and 1524	990, 1067, 1220, 1524	-
8	1220, 1372, and 1524	914, 990, 1067, 1220	-

#### 4.4 Some important Points to be highlighted:

1. Staircase width smaller than 1067 mm (3' 6") could cause traffic congestion and should be avoided.
2. Optimum design of fire door is 1067 mm, fire door smaller or wider than that will not improve the evacuation time.
3. The optimum staircase width is 1067 mm (3' 6") to 1220 mm (4') and corridor width is between 1220 mm (4') to 1524 mm (5')
4. Increasing the corridor width does not improve the evacuation time.
5. Avoid designing an enclosed corridor, but open corridor instead.
6. Fire door is an essential component in escape route because it will help in reducing the possibility of traffic congestion in escape stair.

#### 5.0 CONCLUSION

Properly designed escape routes in high-rise building could save many lives in a fire emergency situation. A decade ago, a number of people dying in fire cases found in escape route quite far away from the fire origin. This possibly happened due to the traffic congestion and those who died might be stepped by other occupants who desperately want to evacuate the building during evacuation process. Well-designed means of escape will usually provide an efficient circulation pattern for the building and vice versa. Cost and time can be saved if means of escape design principles are followed at the earliest stages of a project. Basic design principle should be considered when designing an escape route, i.e. the positions of exits and entrances, corridor patterns and widths, staircase numbers and locations, and the need for lifts.

## REFERENCES:

- Billington, M.J., Ferguson, A., Copping, A.G. (2002), *Means of Escape From Fire*, Blackwell Publishing.
- Canadian Wood Council (CWC), (2000), Fire safety in Residential Buildings, *Building performance bulletin*, series 2. Pg. 3.
- Home Office, (1995), *Fire statistics United Kingdom 1993*. London: Home Office Research and Statistics Department.
- Home Office, (1996), *Fire statistics United Kingdom 1994*. London: Home Office Research and Statistics Department.
- Home Research Office (HRO), (1998), *Fire Statistics United Kingdom 1997*, Issue 25/98,
- Joint Fire Research Organisation (JFRO) (1968), *United Kingdom Fire Statistics 1966*, London, HMSO
- Joint Fire Research Organisation (JFRO) (1970), *United Kingdom Fire Statistics 1968*, London, HMSO
- MacDonald J.N. (1985), Non Evacuation of Compartmented Fire Resistive Buildings can Save Lives and Makes Sense, *Proceedings of International Conference on Building Used and Safety*, Los Angeles, pp 169 – 174.
- MacLennan, H.A., (2001), To Evacuate or Not to Evacuate: Which is the Safer Option, *Proceedings of the 2<sup>nd</sup> International Symposium on Human Behaviour in Fire*, Interscience Communication, pp.477 – 487.
- Office of the Deputy Prime Minister (ODPM), (2003), *Fire Statistics United Kingdom 2001*, ODPM.
- Proulx, G., (1999), How to initiate evacuation movement in public buildings, *Facilities Journal*, Vol. 17 No. 9/10, pp. 331-335, University Press.
- Proulx, G., (2001), High-rise Evacuation: A Questionable Concept, *Proceedings of the 2<sup>nd</sup> International Symposium on Human Behaviour in Fire*, Interscience Communication, pp.221-230.
- Ramachandran, G., (1999), Fire Safety Management and Risk Assessment, *Facilities Journal*, Vol. 17, No 9/10, pp 363 – 377, MBC University Press.
- Shields, T.J., Boyce, K.E., (2000), A Study of Evacuation From Large Retail Stores, *Fire Safety Journal*, 35 pg. 25-49.
- Yatim, Y.M. and Harris, D.J., (2005), *Fire safety Management: Evaluation of Means of Escape in High-Rise Residential Building*, ASIANPGS 2005 Seminar in Built Environment, University Malaya, Malaysia.
- Yatim, Y.M., (1999), High Rise Building Fire Hazard and Prevention Action, *Alam Bina National Journal (UTM)*, Jld. 02, No. 01, pp 33 – 40.
- Yahya, M.Y., (2001), Fire safety in Buildings – Causes and Risks, *Paper presented in National Construction Industry Symposium 2001, Sofitel and Palm Resort, Johor. Malaysia*.
- Yung, D.T., Proulx, G., and Benichou, N., (2001), Comparison of model predictions and actual experience of occupant response and evacuation in two high-rise apartment building fires, *2<sup>nd</sup> International Symposium on Human Behaviour in Fire Proceeding*, Boston ,MA, pp 77-88.
- Yahya, M.Y., (2011), *Fire safety Issues in High-Rise Residential Buildings*, LAP Lambert Academic Publishing, Germany.