

Fire Risk Assessment of Residential Buildings Based on Fire Statistics from Selangor

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Abstract: Fire risk becomes an important issue in building fire safety. In consequence, the incidents kill and injure thousands of people every year, besides the significant damage and loss. This research aims to identify the fire risk for different types of buildings in Selangor using Brushlinsky's Approach. Data regarding fires between 2012 and 2017 was collected from fire investigation reports prepared by the Selangor Fire and Rescue Department. The results showed that most fire cases occur at residential buildings and commercial buildings in which terrace house recorded the highest number with a total of 1,458 cases out of 6,015 cases. Meanwhile, the probability of the fire occurrences building in Selangor is increasing from 0 to 2 case per day. However, the probability of 3 or more fire occurrences in a day is decreasing for each year. The year of 2012 recorded the highest probability of a person facing a fire accident as compared to other years. But the risk of death from the fire fluctuated over the study period. Whereas 2015 had the highest possibility of death for a person in a fire by recorded respective 29 fire deaths per 6.178 million people in Selangor. In conclusion, fire incidents need to be considered as a serious issue by all parties. The findings from this study can be used by the Fire and Rescue Department of Malaysia, government, public and private sectors to curb more fire incidents from happening and develop suitable measures.

Keywords: Building, Fire, Malaysia, Risk, Selangor.

I. INTRODUCTION

Fire incidence is inevitable and can occur every day across the world. The fire incidents pose a significant threat to life, structure, property, and environment that the number of deaths during a fire is rather alarming. Furthermore, this fire represents a severe hazard in both developing and developed countries. Malaysia is one of the developing countries with a population of 32,365,999 billion people [1]. The increasing number of fire incidents in recent years in Malaysia has remained a critical concern. Other than that, fire also constitutes a significant threat to life and property, resulting in harming the nation's economy as a substantial amount of damages and losses incurred every year.

Overall, Malaysia has an average rate of fire incidents at around 1024.67 fires per million populations per year in the 9 years from 2006 through 2014. The rate of fire victims is 7.53 per million populations per year, with 3.07 deaths per million

populations per year [2]. However, these rates gradually increase by 61% of the overall fire deaths per year and 48% of the total fire injuries per year [3]. According to the Fire and Rescue Department (FRD)'s statistics, on average, between 30,000 and 60,000 fire incidents are reported every year, and about 40% of them were private homes. While, the remaining were other types of buildings such as offices, factories, schools and shophouses [4].

With the development and application of quantified fire risk assessment and performance-based fire protection design method in Malaysia, fire statistics face the new challenge. At present, there is a lack of study of quantifying fire occurrence likelihood and fire risk criterion in Malaysia through fire statistics analysis. Furthermore, the statistics of fire incident are crucial and need to be analysed to estimate insurance claims and premiums as well as to develop fire safety measures [5].

So, both fire statistics and analysis on fire statistics are of great importance. The findings from this study also can be used by the Fire and Rescue Department of Malaysia, government, public and private sectors to curb more fire incidents from happening and develop suitable measures.

Therefore, the research questions (RQs) are provided below: -

RQ-1: Which type of buildings are having higher fire risk in Selangor?

RQ-2: What is the probability of fire occurrence of buildings in Selangor?

RQ-3: How fire risk analysis model can be used to measure the risk of fire of buildings in Selangor?

Fire Risk Analysis Model

Building fire risk analysis is a process of understanding and characterizing the fire hazards such as the unwanted outcomes that may result from the fire, and the probability of fire occurrences. The purpose is to evaluate and make a decision about the level of fire risk as well as to measures the appropriate risk management has taken or not. Therefore, building fire risk analysis serves as a basis for fire risk

management. According to the [6] definition, risk management includes risk assessment and risk treatment [7]. There are different stages in fire risk management procedures are illustrated in Fig.1.

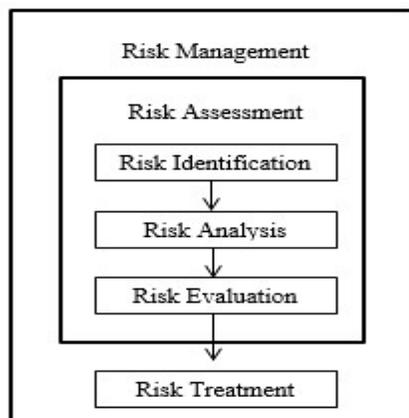


Fig.1 Different Stages in Fire Risk Management Procedures

Source: Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management. *Fire Safety Journal*, 62, 72-78

Fire risk assessment in buildings comprises of three steps which are fire risk identification, fire risk analysis, and fire risk evaluation.

- Fire risk identification is the systematic process to understand how, when, and why fire could happen.
- Fire risk analysis is the process of estimating magnitudes of consequence and probabilities of the adverse effects resulting from a fire in a building [8]. Moreover, it can be defined as the probability of fire occurrence, consequence or extent of damage to be expected on the occurrence of fire [9]. The purpose of fire risk analysis is to allow a quick check of any safety deficiencies in residential buildings and any need to provide additional fire protection measures to minimize fire risk [10]. The result is expressed either in qualitative, mixed or quantitative terms depending on the type of risk, the purpose of risk analysis, how detailed the study is to be and the information resources available.
- Fire risk evaluation involves applying the developed risk criteria and making a decision about the level of fire risk.
- Fire risk treatment is the process of improving existing risk controlling measures, developing new risk controlling measures and implementing these measures to reduce fire risk.

Therefore, fire risk analysis is only one part of fire risk management process, and it serves as the foundation of regulatory decision-making on whether to take actions to reduce risk or choose appropriate risk treatment measures or not [11].

With the development of performance-based design, some studies have been conducted on fire risk analysis in buildings from different perspectives and levels. Models such as FiRECAM [12], [13] and FiERA system [14] were used to calculate the expected life risk. In other studies, probabilistic methods have been used to assess levels of people safety in buildings [15]. Quantitative risk analysis approaches have also been used to quantify the risk to occupants using stochastic factors [16].

In this paper, the pattern of fire accident is constructed in the process of building fire risk analysis in Selangor, and the number of fire cases according to fire stations in Selangor were used to assess the probability of fire occurrence. Finally, the average fire risk of residential buildings is quantified in detail. With the types of detailed fire risk models developed here, fire risk management measures could be taken to improve the building fire safety grading and reduce fire risk levels and subsequent damage.

II. METHODOLOGY

Data Structure

In fire analysis, there are two secondary data obtained to help acquaint the risk to life caused by fire. The first one is the secondary data collected from the Operational Management Branch of Selangor Fire and Rescue Department were taken from the year 2012 until 2017. The data consist of the number of fire cases according to types of building, the number of fire cases according to fire stations, the number of deaths according to fire stations in Selangor and causes of fire according to fire stations in Selangor. All these data were recorded annually. Secondly, the secondary data of Malaysia population distribution by the state were acquired from the year 2012 to 2017 from the Department of Statistics Malaysia.

Poisson Distribution

The probability of fire occurrence in Selangor can be estimated using the total number of fire cases from the year 2012 to 2017 and the number of fire cases based on 34 fire stations in Selangor. Poisson distribution was used to predict the number of fire occurrences in time interval by assuming that fires occur follow the Poisson process. Poisson distribution is a discrete probability distribution for the number of events in each interval of time that occur randomly [17]. In other words, fire cases are assumed to occur randomly and independently. Let X is the number of fire occurrences per day. Thus, the probability of observing X events in a given interval is given by

$$P(X = x) = \frac{e^{-\lambda} (\lambda)^x}{x!}, \quad x = 0, 1, 2, \dots \quad (1)$$

Where:

X = The number of fire occurrences in a day

λ = The average number of fire occurrences per day

$P(X = x)$ = The probability that there are x fire occurrences in a day

Then, the average number of fire occurrences on building in Selangor for 6 years per day can be written as

$$\lambda = \frac{\text{Total number of fire cases per year}}{365 \text{ days}} \tag{2}$$

Brushlinsky’s Approach

According to [18], the term fire risk is a parameter that characterises the quantitative possibility of the realisation of such a potential fire hazard (in the form of a fire) and includes the evaluation of the consequences a fire may have. In many cases, the fire risks can be determined by applying the methods of statistics and theory of probabilities [18].

By using Brushlinsky’s approach, the evaluation of fire risks can be divided into three aspects which are the probability of a person facing a fire, death risk at a fire, and death risk for a person in a fire [19]. Then, the probability of a person facing a fire is given by

$$R_1 = \frac{\sum F}{\sum P} \tag{3}$$

Where:

R_1 = Probability of a person facing a fire

F = Number of fire cases

P = Number of populations

Thus, the probability of a person facing a death at fire is given by

$$R_2 = \frac{\sum D}{\sum F} \tag{4}$$

Where:

R_2 = Death risk at a fire

D = Number of deaths

F = Number of fire cases

Then, the probability of death risk per capita is given by

$$R_3 = \frac{\sum D}{\sum P} \tag{5}$$

Where:

R_3 = Death risk for a person in a fire

D = Number of deaths

P = Number of populations

Note that there is a simple relationship between R_1 , R_2 and R_3 . By equating (3) and (4), it yields

$$R_1 \times R_2 = \frac{\sum F}{\sum P} \times \frac{\sum D}{\sum F} = \frac{\sum D}{\sum P} = R_3 \tag{6}$$

Therefore

$$R_3 = R_1 \times R_2 \tag{7}$$

III. RESULT AND ANALYSIS

Analysing Pattern of Fire Accident

According to Fire and Rescue Department Malaysia recorded a total of 6,015 fire cases or approximately 1,003 cases annually from the year 2012 until 2017 in Selangor. Malaysia had recorded on average, approximately 1,025 fire cases per million population for the 9 years from 2008 to 2014 [2]. Even though the duration of this study differs from the study conducted by [2], the average of fire cases depicts that Selangor is the state which had the highest number of fire cases in Malaysia.

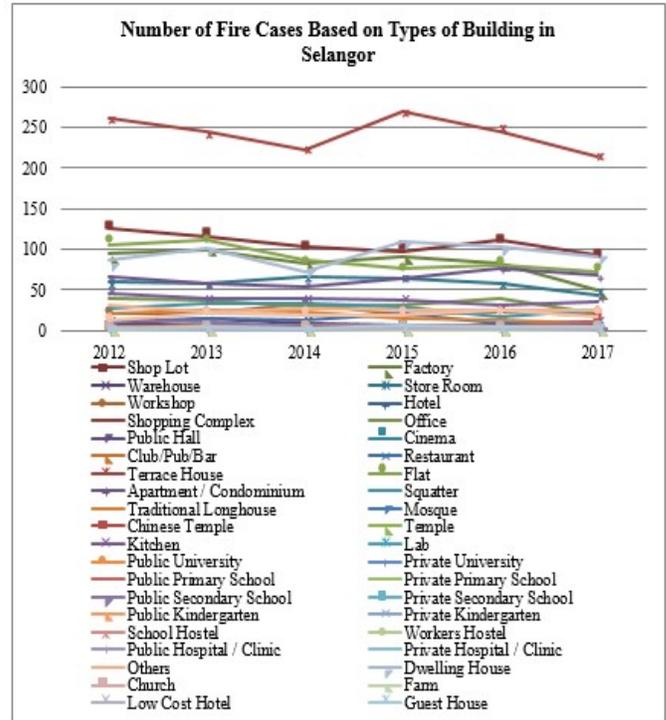


Fig.2 Fire Cases in Selangor According to Types of Building for Year 2012 until 2017

Source: Fire and Rescue Department Malaysia

Fig.2 shows a line graph of the number of fire cases according to the types of building from the year 2012 until 2017 in Selangor. There are 41 types of building that had been involved in the fire for 6 years. During the 6 years, terrace house recorded the highest number of fire cases with a total of 1,458 cases out of 6,015 cases. In contrast, the church marked the lowest number of fire cases with only 1 case in total.

Besides that, shop lot, dwelling house, flat, and factory showed a higher number of fire cases compared to other buildings which were approximately more than 400 cases in 6-year. Meanwhile, farm, private kindergarten, and cinema showed a lower number of fire cases which were less than 5 cases in 6-year.

The data illustrated that most fire cases occur at residential buildings and commercial buildings. Many factors can lead to the ignition of fire in residential buildings and commercial buildings compared to other types of building such as short circuit and fire started from cooking or the use of candle. In contrast, places that rarely visited by people had the lowest fire cases since fewer people involved in its daily operations.

Findings on Probability of Fire Accident

In this analysis, data of fire statistics from the year 2012 until 2017 on building in Selangor is used to determine the probability of fire occurrence for different types of building in the particular year.

Table 1 Probability of Fire Occurrences \mathcal{X} in a Day for Year 2012 until 2017

Year	Total of fire cases	λ	P(X=0)	P(X=1)	P(X=2)	P(X=3)
2012	1081	2.9616	0.0517	0.1532	0.2269	0.2240
2013	1085	2.9726	0.0512	0.1521	0.2261	0.2240
2014	964	2.6411	0.0713	0.1883	0.2486	0.2189
2015	1031	2.8247	0.0593	0.1676	0.2367	0.2229
2016	1003	2.7479	0.0641	0.1760	0.2419	0.2215
2017	851	2.3315	0.0971	0.2265	0.2640	0.2052

The results shown in Table 1, indicate that the probability of fire occurrences \mathcal{X} on different types of building in Selangor is increasing from 0 cases to 2 cases per day. Besides, the probability of 2 fire occurrences in a day recorded the highest for each year. However, the probability of 3 fire occurrences in a day is decreasing for each year.

Therefore, Fire and Rescue Department, government and private sector such as insurance company can depend on such probability to estimate the expected number of \mathcal{X} fire occurrence in a day on building in Selangor.

Analysis of Fire Risk

Brushlinsky’s approach was used to predict the probability of a person facing a fire, death risk at a fire and death risk for a person in a fire. It is crucial to recognize threats as well as to find risk mitigation measures to understand statistical fire data [19].

Table 2 Evaluation of Fire Risk for People by using Brushlinsky's Approach

Year	Probability of a person facing a	Death risk at a fire, R_2	Death risk for a person in a fire, R_3
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	fire, R_1		
	[total fires/population]	[total deaths/total fires]	[total deaths/population]
2012	0.1896	0.0176	0.0033
2013	0.1838	0.0157	0.0029
2014	0.1593	0.0280	0.0045
2015	0.1669	0.0281	0.0047
2016	0.1594	0.0199	0.0032
2017	0.1334	0.0223	0.0030

Based on Table 2, the probability of a person facing a fire is the highest in 2012 as compared to other years. The probabilities were decreasing in 2013 and 2014, but there is a slight increase in 2015. However, the probability for the next two years started to decrease again in which 2017 recorded the lowest probability during the six years period. There are several possible explanations for this result. The year 2012 had the highest probability of a person facing a fire as compared to other years is apparent from the data provided by Fire and Rescue Department Malaysia that the most significant cause of fire occurrence in 2012 was others. Others caused about 877 fire cases, followed by 79 fire cases were caused by electrical equipment, and an unknown cause caused 59 fire cases. Stoves caused another 45 fire cases.

However, these results were not very encouraging. The unknown cause of fire occurrence should be investigated further, not only to improve data quality but also to achieve higher accuracy from the analysis. Moreover, the critical reasons for a continuously high probability of fires ignited by electrical equipment and stoves in Selangor also can be analysed. According to [19], there are various ways to reduce hazards caused by fire. For instance, ensure all electrical, mechanical and gas equipment is installed, used, maintained and protected in accordance with the manufacturer’s instructions as well as ensure that all electrical fuses and circuit breakers are suitable for the right purpose and that electrical sockets are not overloaded.

Another possible explanation for this is that in the third column, death risk at a fire showed fluctuations throughout the period from the year 2012 to 2017. According to [21], domestic smoke detectors do save lives and vital to reduce the risk of death and injury in the home. Therefore, fire safety in the house should be increased by moving towards the provision of residential sprinklers and drenchers [21]. A sprinkler system protects a building from internal fire. In contrast, drenchers which are located on roofs, over windows and external openings preserve the building from damage by exposure to a fire in adjacent premises [21].

As portrayed by the findings, 2015 had the highest possibility of death risk for a person in a fire by respective 29 fire deaths per 6.178 million people in Selangor. The risk of fire death is the most serious issue for people facing a fire [19]. For this

reason, the provision of fire blankets and simple fire extinguishers can be useful in restricting the development and spread of small fires in their early stages [22]. However, unless a fire is very small, the best advice is to evacuate the building to a place of safety and call the fire and rescue service [22].

IV. CONCLUSION

In a nutshell, most fire occurred in residential and commercial areas. Every year, fire was reported with some involving death and huge amount of loss. Even though 2015 reported highest cases of fire, the number then went down in year 2016 and 2017. This is most probably because of awareness regarding fire is increasing slowly over the year. Campaigns done by Fire and Rescue Department and government have eventually changing people's mind set.

The analysis made by using Poisson Distribution showed that fire occurrences on building in Selangor is increasing from 0 cases to 2 cases per day. The probability of 2 fire occurrences in a day is the highest for each year. However, the probability that there are more than 2 fire occurrences in a day is decreasing.

Brushlinsky's Approach used in the analysis of the probability of a person facing a fire each year showed that the year 2012 recorded the highest probability. However, the number had gone down in 2017 which indicates that it is possible to reduce the probability of a person facing a fire. Since most fire cases were recorded in terrace houses, there are many possible fire hazards. Fire hazards like kitchen fire and overloaded electrical systems should not be taken for granted. It can be reduced if the right method is applied.

At the same time, death risk was estimated for six years by using the same approach. Death risk at a fire was the highest recorded in 2015. The number then dropped but increased again in 2017. This is also a concern matter since there is death risk in every fire occurrence and it is just a matter of high or low. Next, death risk for a person in a fire recorded unstable number which fluctuated over the 5-year period. Even though the number is quite low, the death risk still exists when such thing happened.

V. RECOMMENDATION

Authorities must work hand in hand toward a better fire safety system in Malaysia. Campaigns must be conducted aggressively, especially toward children who are essential to nurturing their mindset before they grow up. The government must establish more strict regulations, especially in residential and commercial areas, since fire tends to happen in those two areas. Fire extinguisher, fire blanket, and the smoke detector should be made as necessary things to have in each resident's house [10]. Failure to comply should then lead to a fine.

On the other hand, Malaysia Fire and Rescue Department must continuously remind the public not to renovate or build a house without seeking advice or approval from authorities.

The public should also prepare their home escape plan and ensure all windows along with doors are open easily [23]. Lastly, government, private sectors and the public must also always upgrade and improve the facilities in their buildings. Every building should comply with regulations and should make it easy for people to escape from fire. Hence, everybody must play their role and put some effort into this matter to be curbed.

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