

Preliminary Investigation on Possible Fire Causation in Multistorey Buildings in Selangor

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Abstract

The development of high and complex multistorey buildings has increased dramatically over the past 20 years, leading to new and updated approaches to the provision of appropriate fire safety rules. Multistorey buildings record the highest number of fire incidents compared to other types of buildings in Malaysia. Hence, this study aims to investigate possible causes of fire incident in multistorey buildings. A comprehensive literature review along with interviews were conducted to explore the factors causing multistorey building fires. These exercises were conducted to identify the fire scenario (characteristics of fire, building and occupant), possible causes of multistorey building fire, and means to reduce the possibilities and causes of multistorey building fire incidents. Preliminary interviews with three (3) respondents who are involved in the construction and maintenance of multistorey buildings in Selangor were first conducted. The respondents have either designer, maintenance personnel or local authority backgrounds. Based on the data obtained, the top possible causes of multistorey building fires are electrical failure, cooking, smoking, sparks, and poor maintenance of building's fire safety. Some means that can be employed to reduce the possible causes of multistorey building fires involve increased fire safety awareness and human behavior among building occupants, good building layout and materials, improved and regular maintenance of buildings, active and passive firefighting equipment and knowledge, and reduced usage of unsafe and defect electrical equipment. This study may help add new information to the existing body of knowledge on the risk of fire cases, fire injuries and fire fatalities in multistorey buildings in Malaysia. Besides, it may also be used by building occupants, designers, developers, property managers, staff working on/in community house, maintenance personnel, and local authorities. It can also serve as a requirement enforced by the government and help improve current research on the efficiency and cost-effectiveness of building design and construction. Lastly, it can also provide a higher overall quality of life for people who live and work in multistorey buildings.

Keywords: Causes of fire, fire scenario, multistorey building fire, reduce fire, fire evacuation

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01.0 INTRODUCTION

Fire disasters are an anthropogenic hazard, and most incidents involve fires in buildings (Lee et al., 2020). Fire is combustion that is not controlled – it involves the evolution of light and energy in order to be perceptible, is energetic enough to be sensed, and is a chemical reaction that involves fuel and an oxidizer which typically exists in the air (Quintiere, 2016). Failure to consider the factors causing building fire may lead to the underperformance of existing fire safety systems in multistorey buildings which in turn, may endanger human lives (Rathnayake et al., 2020). The location and development of building fires are very random, therefore accurate evacuation route guidance is needed in order to be able to evacuate people as soon as possible and reduce casualties (Ma et al., 2017).

According to Timbuong (2020), in the period between March until August 2020, firefighters had to deal with 7,032 cases (46%) of open burning, whereas another 1,955 cases were classified as structural fire which includes fires in buildings and other smaller structures. Almost half of these structural fires were caused by electrical faults which accounted for 49.1% of fires, followed by leaking of gases (17%) and sparks (14%). Accordingly, the failure to consider the causes of building fire has led to the underperformance of existing fire safety systems in buildings (Rathnayake et al., 2020).

Smaller percentages of fire incidents (between 2% to 7%) were caused by flammable items such as matches, lighter and candles (Timbuong, 2020). It was also found that almost 40% of building fires had occurred in multistorey buildings such as flats, apartments and condominiums (Tan et al., 2016). Fire can pose a serious threat to human life as well as property and assets (Dickinson, 2019). House fires can cause fatalities if there is a lack of fire safety measures (Timbuong, 2020). Therefore, the common causes of fire need to be considered, and means to reduce the risk of building fire should be taken (Dickinson, 2019).

02.0 LITERATURE REVIEW

2.1 Fire Scenario

Incidents of fire in multistorey buildings are on the rise, with most of fires occurring in residential buildings (Salankar et al., 2018). Fire is defined as a chemical reaction between heat, or an ignition source, with fuel and oxygen; it is necessary to remove one of those elements in order to stop the fire (OSHA, 2018). In the event of fire, it is important to quickly identify the location of building occupants in order to provide rapid evacuation guidance and minimize casualties (Lee et al., 2019). Minimum congestion, shortest evacuation time and shortest total evacuation route are factors important to be considered in planning multistorey building emergency evacuations (Zhang et al., 2019). Evacuation of multistorey buildings can be inefficient when building occupants have to encounter many difficulties in identifying the evacuation situation (Lee et al., 2019). According to Glauberma (2020), fire safety refers to the prevention of fire, the limited spread of fire and smoke, the extinguishing of fire, and also fast and safe evacuation.

Hence, it is important to identify the characteristics and classification of building fire in order to select the correct method and agent to be used to extinguish the fire (FEMA, 2011). Figure 1 shows the characteristics and classification of fire scenarios that need to be considered. The characteristics consist of size, shape, duration, rate of spread, and smoke emissions, while fire classification is divided into five classes including Class A, Class B, Class C, Class D, and Class K.

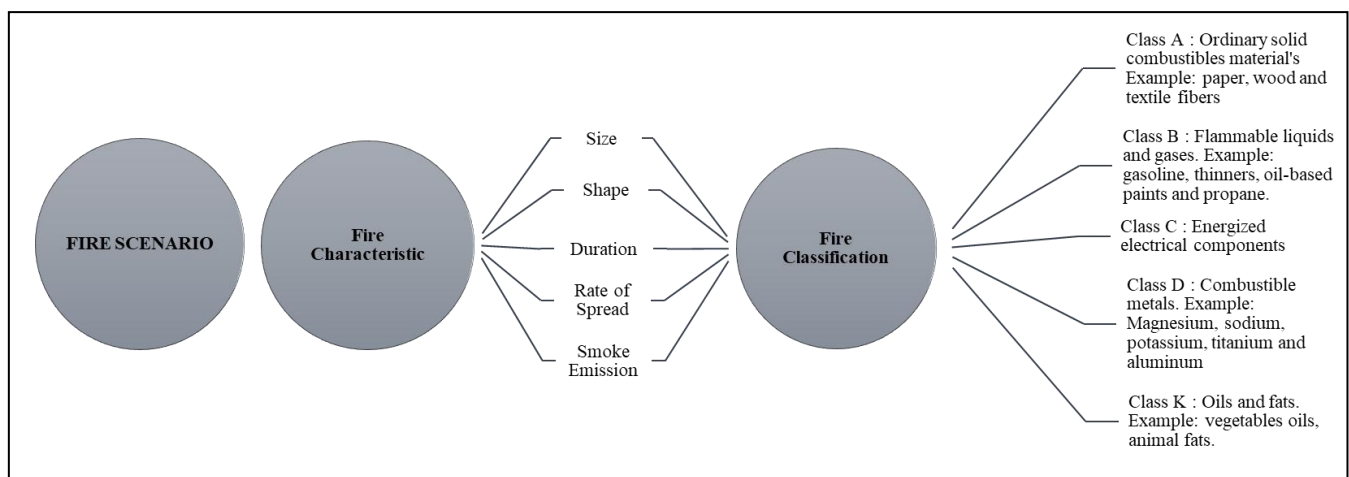


Figure 1 Fire scenarios

2.1.1 Fire Characteristics

Fires frequently occur in residential and commercial mixed-use areas as well as in populated areas - this is due to the fact that it is highly correlated with the urbanization of a location itself (Lee et al., 2020). According to Sun and Turkan (2020), a fire’s growth conditions consist of the movement of fire dynamics in terms of fire temperature, toxicity and smoke conditions. It is important to locate the existence of fire ignition, narcotic gases, irritant gases, heat, smoke, and toxic gases in order to identify the escape movements of occupants required for safe evacuation (Salankar et al., 2018).

Fire characteristics such as size, toxicity and ignition are important elements to consider when efforts are taken to decrease the number of fatalities caused by fire (Andersson et al., 2015). The probability of fire disaster is normally forecasted using fire probability, while the degree of fire damages from a disaster is often represented by fire severity (Lee et al., 2020).

2.1.2 Fire Classification

According to Occupational Safety and Health (OSHA, 2018), fire can be classified and categorized based on the material that fuels the fire. Table 1 summarizes the classifications of fire which include Class A, Class B, Class C, Class D and Class K. This classification may help in choosing the most appropriate type of fire safety equipment.

Table 1 Fire classification

Class	Material
A	Ordinary solid combustible materials Example: paper, wood and textile fibers
B	Flammable liquids and gases Example: gasoline, thinner, oil-based paint and propane.
C	Energized electrical components

D	Combustible metals Example: magnesium, sodium, potassium, titanium and aluminium
K	Oils and fats Example: vegetables oils, animal fats

2.2 Building Characteristics

Building is an infrastructure where humans live, and humans need protection during a fire outbreak (Yenumula et al., 2015). Inappropriate guidance and lack of facility management may pose risks during a fire evacuation process (Yenumula et al., 2015). Figure 2 shows the building characteristics that need to be considered when planning for fire safety of a multistorey building. Building elements include layout, material, size, maintenance, density, way-finding, compartment, safety features, technology, location of occupants, and also firefighting equipment. Additionally, building characteristics may also include the elements of building layout, building material, size, maintenance, density, wayfinding, compartment and building safety features (Kobes et al., 2008). Generally, fire alarm and evacuation announcement broadcasts are uniformly performed during a fire disaster (Lee et al., 2019). However, many occupants are not aware of the fire safety features in their buildings (Glauberma, 2020).

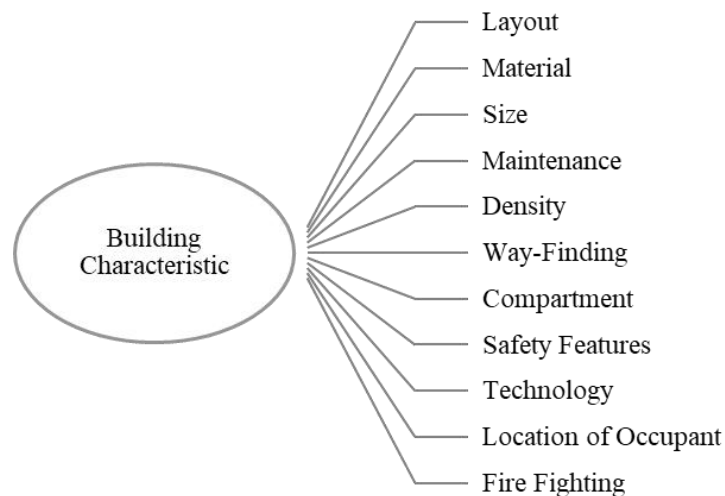


Figure 2 Building characteristics

Fire safety in multistorey or high-rise buildings is one of major challenges that need prioritization for ease of firefighting and evacuation. This is due to the fact that fires may spread very fast if there are no proper precautions taken, more so at shared building features such as stairways, elevator shafts, pipes, ducts, and electrical shafts (Salankar et al., 2018). During a fire evacuation, it is necessary to identify and understand how to use a building's location identification technology using information on the building's size and also the location of occupants inside the building in order to make reasonable choices for efficient evacuation guidance in the face of limited information and space (Lee et al., 2019).

A building's egress system elements such as fire-rated doors, panic hardware, stairwells, elevators, escalators, emergency lighting, exit passageways, refuge areas, and smoke control are also the core components that are important to be considered when making sure that a building is capable of withstanding stresses imposed by a fire (Chen, 2019). It is important to note that the use of building cladding systems may increase difficulties in firefighting and rescue and may result in an increase in evacuation time (Salankar et al., 2018). Additionally, the complexity of building structure, material used for external and internal finishes, and crowd evacuation may also influence fire behavior in multistorey buildings (Gerges et al., 2017).

2.3 Human Characteristics

Human characteristics can be classified into several elements such as personality, behavior, age, knowledge and experience, movement, awareness, physical, familiarity and body size (Kobes et al., 2008). The same notion was also stated by Fang et al. (2020) who classified human characteristics into categories such as sex, evacuation experience, age, and education level. According to Timbuong (2020), about 56% of those killed by fire events recorded between March and August 2020 were 60 years old and above. This high number may be caused by these occupants' higher rates of immobility due to poor health and smoke inhalation. Old-aged and disabled people can be a challenge to safe evacuation, and they may also cause obstruction and hold ups in passageways (Gerges et al., 2017). Therefore, the pre-evacuation period is when escape routes should be presented, and this is driven by social behavior (herding behavior/ crows' attraction/ individual behavior/familiarity) (Sun & Turkan, 2020).

Human fire behavior is one of the key factors determining how occupants' react during a fire emergency as it influences the decision-making process of an individual, more so regarding concerns on the lack of proper behavior during evacuation, and lack of attention to risk

perception during fire (Mousavi et al., 2019). Human behavior may also include reactions such as disaster shock, panic behavior, re-entry behavior, firefighting behavior, protecting behavior, and group behaviors (Chen, 2019). Moreover, human characteristics may also refer to a person's emotional state, gender, age and cognitive abilities (Kinatader et al., 2015). It has been found that humans tend to make decisions during fire breakouts based on experience, knowledge and initial cues (Gerges et al., 2017).

Figure 3 summarizes the human characteristics and fire behavior that are normally referred to when accounting for fire safety in multistorey buildings. The human characteristics identified include personality, behavior, age, knowledge/education, experiences, movement, awareness, physical, familiarity, body size, sex, and health condition. Meanwhile, human fire behavior are further classified as panic behavior, disaster shock, re-entry behavior, fire fighting behavior, protecting behaviors, group behavior, and decision making behavior.

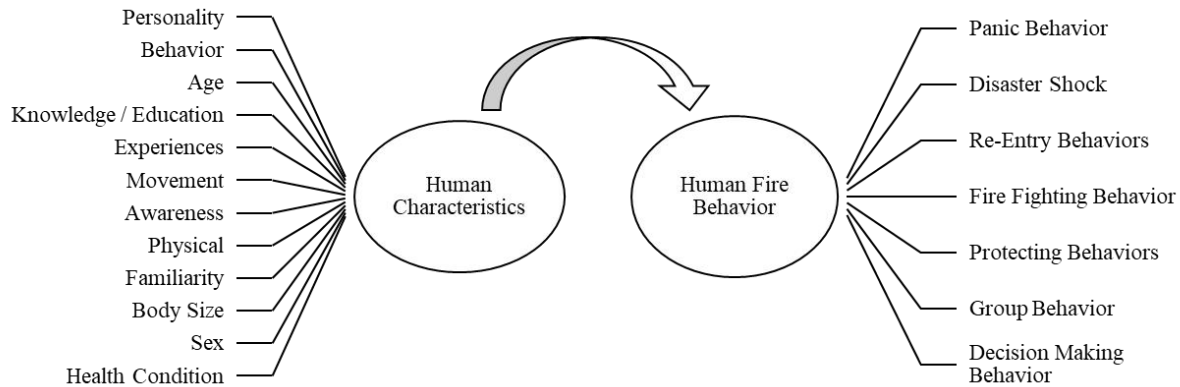


Figure 3 Human characteristics and human fire behavior

2.4 Causes of Multistorey Building Fires

Table 2 shows the possible causes of fire incidents in multistorey buildings as stated by previous researchers. The list includes smoking, cooking, candles, heating appliances, heat sources close to combustible material, and electrical fault/defect. Besides that, carelessness, arson, lighting, forgotten stoves, technical malfunctions, leaking of gas, improper use of fire in daily life, a disregard of safety rules, poor maintenance, and vandalism are also possible causes leading to fire incidents.

Table 2 Causes of fire as listed by previous researchers

Cause of fire	Author(s)
Smoking (cigarette, cigar or tobacco)	Ahrens and Maheshwari (2021); Dickinson (2019); Lawal et al. (2018); Lee et al. (2020); NFPA (2021); Tasmania Fire Service (2022); Zhou (2017)
Cooking	Ahrens and Maheshwari (2021); Chew (2017); Dickinson (2019); Kodur et al. (2020); NFPA (2021); Tan et al. (2016); Tasmania Fire Service (2022); USFA (2021)
Carelessness	Lawal et al. (2018); Tan et al. (2016); USFA (2021)
Arson	Kodur et al. (2020); Lawal et al. (2018)
Candles	Ahrens and Maheshwari (2021); Mtani and Mbuya (2018); Tasmania Fire Service (2022)
Heating appliances	Adekunle et al. (2016); Ahrens and Maheshwari (2021); Dickinson (2019); Kodur et al. (2020); Lawal et al. (2018); Tasmania Fire Service (2022); USFA (2021)
Heat sources close to combustible materials	Adekunle et al. (2016); Kodur et al. (2020); Lawal et al. (2018); Lee et al. (2020); Mtani and Mbuya (2018); USFA (2021); Zhou (2017)
Electrical fault/defect	Adekunle et al. (2016); Ahrens and Maheshwari (2021); Chew (2017); Dickinson (2019); Kodur et al. (2020); Lawal et al. (2018); Lee et al. (2020); Mtani and Mbuya (2018); Quintiere (2016); Tasmania Fire Service (2022); Zhou (2017)
Lighting	Ahrens and Maheshwari (2021); Lawal et al. (2018)
Forgotten stove	Lawal et al. (2018); Mtani and Mbuya (2018)
Technical multifunction	Kodur et al. (2020); Lee et al. (2020); USFA (2021)
Leaking of gas	Lawal et al. (2018); Mtani and Mbuya (2018); Zhou (2017)
Improper use of fire in daily life	Zhou (2017)
Disregard of safety rules	Mtani and Mbuya (2018)
Poor maintenance	Kodur et al. (2020); Mtani and Mbuya (2018)
Vandalism	Kodur et al. (2020)
Unknown	Chew (2017)

According to Mtani and Mbuya (2018), the risk of fire arises from inappropriate and unsound behavioural practices such as the unsafe practice of electrical usage, poor capacity of fire fighting amongst occupants, limited access to firefighting equipment within the building, and inadequate awareness among responsible parties. This idea is also supported by the National Fire Protection Association (NFPA, 2021) which stated that cooking and smoking remain the main leading causes of home fires. Besides that, overheating is also an accidental cause of fire which results from two conditions, which are: (1) fire that heats a conductor from the outside, or (2) the overheating of a source such as cooking appliance, along with appliance malfunction, explosion, smoking, or rubbish fires (Lawal et al., 2018). Thus, it does seem that the kitchen is the most popular location of fire origin due to the large amount of fire sources that it houses such as electrical appliances, cooking gas, and cooking appliances (Tan et al., 2016).

Furthermore, lack of training for staff and lack of regular fire drills are factors that may worsen a building fire situation. Therefore, there is a need for regular fire risk assessments to be carried out in order to identify possible risk and prevention measures (Lawal et al., 2018). Some common causes of fatal fires include smoking, forgotten stoves, candles, technical malfunction and heat transfer (Andersson et al., 2015). In addition, human factors such as carelessness, negligence and lack of fire safety awareness are also reasons behind fire outbreaks (Lawal et al., 2018). This notion is also supported by Rathnayake et al. (2020) who stated that careless smoking in refurbishments, along with sloppy maintenance of electrical tools, faulty wiring and lack of adequate fire watch are considered as common human errors in fire cases.

2.5 Reduction to Causes of Building Fire

According to Dickinson (2019), ensuring all building occupants use proper equipment for cooking as well as having adequate fire prevention and suppression training can help prevent fires from spreading. Structural fires can also be reduced by raising the community's awareness on fire safety, particularly in residential buildings where most fire cases occur (Chew, 2017). To further reduce the risk of fire, building authorities must ensure that smoking is forbidden on the property, and proper cigarette ashtrays are installed at a safe distance from the building (Dickinson, 2019). Furthermore, policy improvement and intervention development can be established based on statistical reports and feedback on fire performance; this in turn may increase the public's awareness regarding the issue (Rahim, 2015).

In addition, one of the measures that can be considered by homeowners in preventing fire is to conduct assessment and maintenance of electrical wiring every 10 years. This can be done by evaluating and looking for damaged or substandard wiring in the system since many incidents of building fires are caused by electrical faults (Timbuong, 2020). Additionally, building occupants need to conduct regular inspection and maintenance of all heating systems in order to prevent overheating and malfunction as these issues may cause fire to occur (Dickinson, 2019). Besides that, preparation of firefighting and prevention tools such as fire extinguisher, smoke detector and also identification of escape route for each floor are good precautionary measures (Timbuong, 2020). The provision of fire training along with education on fire evacuation preparedness may further improve a multistorey building's occupants ability to quickly recognize an emergency fire situation and in turn, decrease the time they take to initiate and complete evacuation (Glaubergerman & Qureshi, 2018).

Another method to reduce the causes of building fire is regular maintenance of exit ways at a building's entry points, together with other methods such as increasing building occupant's familiarity, making voice announcements during fire emergencies, and increasing the risk perception of individuals through the provision of knowledge and increased awareness on ways to reduce evacuation time during fire emergencies (Mousavi et al., 2019). To go the extra mile, effective alarm systems can also be designed for people with disabilities and also young people. This can be done with the inclusion of built-in shaking alarms in a wheel chair or bed and the setting of pre-recorded parents' alerting voice as alarm in young children's bedroom (Chen, 2019).

Figure 4 summarises the elements that can be adopted to reduce the causes of building fires. They consist elements of using proper equipment for cooking, conducting fire prevention and suppression training, raising fire safety awareness, forbidding smoking areas, policy improvement, regular assessment and maintenance of electrical wiring and heating systems, providing firefighting and prevention tools, providing fire training and education, and lastly regular maintenance of emergency signage.

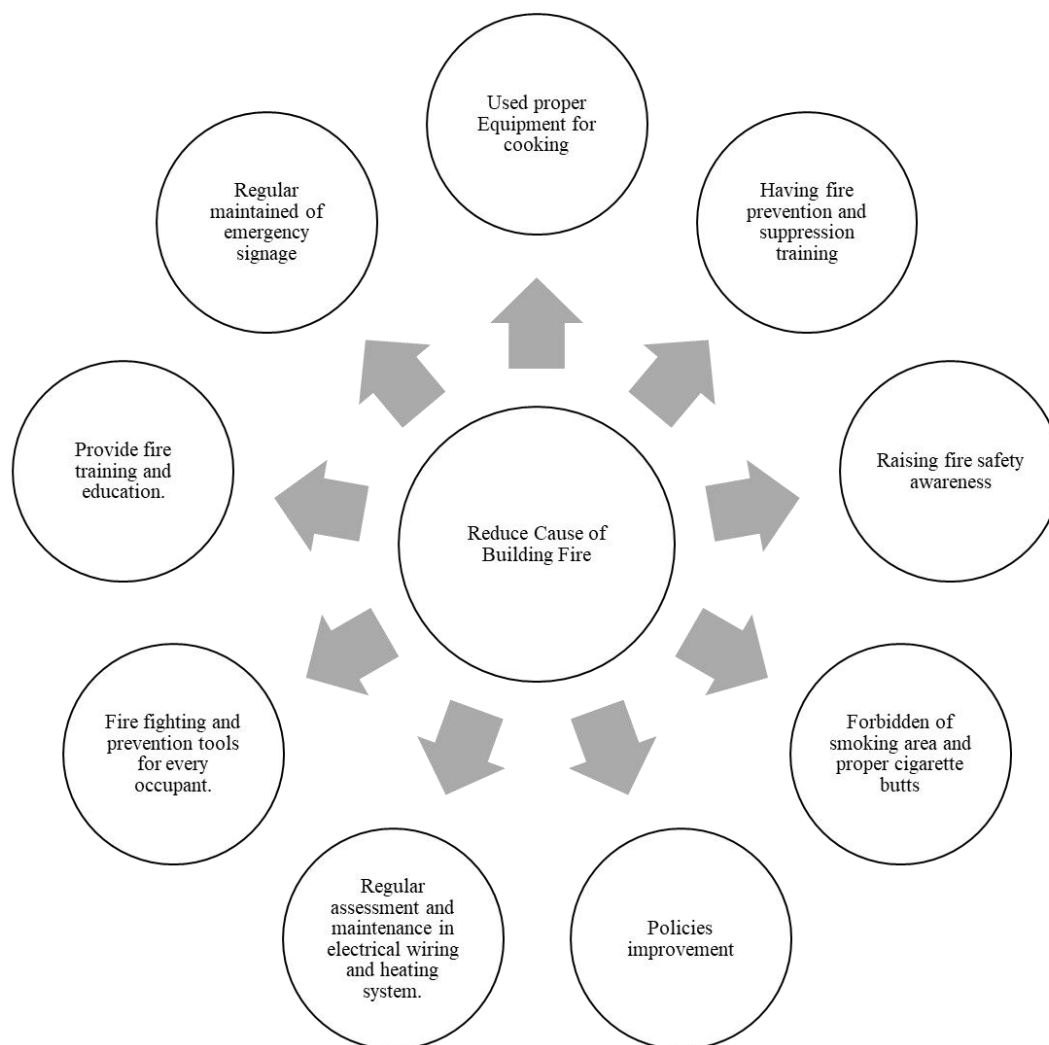


Figure 4 Ways to reduce causes of building fires

03.0 METHODOLOGY

The aim of this research is to investigate the factors that lead to fire incidents in multistorey buildings. The methods used for this paper are a thorough review of literature and also by means of interviews. During the literature review process, 45 papers were reviewed. However, only 26 papers were selected to be included in this study, and the sources include journals, conferences proceedings, and reports. The qualitative data collection method was enhanced by the conduct of face-to-face semi-structured preliminary interviews with three (3) respondents who are directly involved in the construction and maintenance of multistorey buildings in Selangor. Each interview took roughly one to two hours to finish. The three respondents who took part in this study consist of a designer, a maintenance personnel and a firefighting agent, and they have an average work experience of 10 to 15 years in their respective fields. The respondents were selected due to their responsibility and direct contribution to fire risk outcomes in multistorey buildings. The purpose of the interview study is to get insight on the possible causes of multistorey building fires and ways to reduce fire risk possibility in multistorey buildings.

04.0 FINDINGS

4.1 Possible Causes of Multistorey Building Fires

Table 3 shows the possible causes of multistorey building fires mentioned by the 3 respondents during the preliminary interview sessions. From the data given, it can be identified that the top causes of fire outbreaks mentioned by Respondents 1, 2 and 3 are faulty electrical appliances (100%), cooking (100%), smoking (100%) and poor maintenance of electrical appliances (100%) – these causes mirror the data obtained from previous research as mentioned in the literature review. The finding is also in line with previous research conducted by Ahrens and Maheshwari (2021).

Table 3 Causes of fire in multistorey buildings

Cause of fire	Respondent 1	Respondent 2	Respondent 3	Count	Percentage
Faulty electrical	/	/	/	3	100%
Cooking	/	/	/	3	100%
Smoking	/	/	/	3	100%
Carelessness in fire handling	/	/		2	66.67%
Poor electrical maintenance	/	/	/	3	100%
Arson-intended ignition	/		/	2	66.67%
Candles	/		/	2	66.67%
Matches or lighter	/		/	2	66.67%
False detector		/		1	33.33%
Gas leak		/		1	33.33%
Sparks			/	1	33.33%
Mosquito coil			/	1	33.33%
Spontaneous combustion			/	1	33.33%
Chemical reaction			/	1	33.33%
Fire crackers/fireworks			/	1	33.33%

Among the possible causes of multistorey building fire as mentioned by Respondents 1 and 2 is carelessness in fire handling (66.67%). This is also supported by previous research done by Lawal et al. (2018). Besides that, arson (66.67%), candles (66.67%) and matches or lighter (66.67%) are also stated as causes of multistorey building fire by Respondents 1 and 3. Furthermore, Respondent 2 identified gas leaks (33.33%) as also a cause leading to fire outbreaks. Additionally, mosquito coils (33.33%), spontaneous combustion (33.33%), chemical reactions (33.33%) and firecracker/fireworks (33.33%) are also causes of fire ignition in buildings.

4.2 Ways/Means to Reduce Possibility of Fire in Multistorey Buildings

Table 4 shows the methods that can be employed to reduce the possibility of fires in multistorey buildings as obtained from the preliminary interviews. From the data collected, it can be identified that the most suitable method to be employed to reduce possible causes of fire is by increasing awareness (100%), increasing knowledge (100%), and improving guidelines (100%). These are followed by using human sense (66.67%), providing emergency response team (33.33%), proper maintenance (33.33%), and precautionary measures (33.33%). These findings are in line with previous research conducted by Chew (2017) and Dickinson (2019).

Respondents 1 and 3 stated that awareness is the most important element that needs to be considered as only awareness and knowledge may help reduce causes of fire and increase the alertness of occupants of their own building. Besides that, Respondent 2 specified that human sense, knowledge, information, and clear evacuation routes will help ensure safe evacuation in the event of a fire. This is in line with previous research which stated that the first stage of people's response and behaviour will have a significant impact on the ability to reach a safe place in the time given (Lovreglio et al., 2016). In addition, Gerges et al. (2017) also found that educated people tend to leave a building on fire immediately compared to uneducated people who are more likely to undertake other tasks before evacuating the building.

Table 4 Methods to reduce possible causes of multistorey building fires

Method	Respondent 1	Respondent 2	Respondent 3	Count	Percentage
Awareness	/	/	/	3	100%
Human Sense		/	/	2	66.67%
Knowledge	/	/	/	3	100%
Guidelines	/	/	/	3	100%
Emergency Response Team		/		1	33.33%
Proper Maintenance			/	1	33.33%
Precautionary Measures	/			1	33.33%

Furthermore, Respondent 1 stated that the current strategy being applied for multiple use in multistorey buildings is not really focused on the occurrence of building fires. Nevertheless, precautionary measures have to be taken to increase fire safety due to the large number of occupants in multistorey buildings. This notion is also supported by Respondents 2 and 3 who stated that written emergency procedures will be helpful for fire evacuations as it provides information to the fire marshal and building occupants on the layout and emergency evacuation routes of the building. However, the procedure must be kept up-to-date and is on par with fire technology innovations. Additionally, Respondent 2 indicated that buildings need to have an emergency response team for early response when a fire breaks out.

Respondent 3 also stated that all buildings should conduct proper maintenance of emergency utilities, especially for fire disasters. This is also suggested by Mtani and Mbuya (2018) who stated that fire risks can be reduced through the planning of a suitable and proper fire system, along with the maintenance of proper cooking appliances and establishment of community-based fire risk management in all multistorey buildings. Besides that, frequent replacement of defective electrical cords, purchase of electrical goods that have the safety standard approval, and positioning of inflammable materials well away from high risk areas are also ways that can be taken to reduce the risk of fire in all buildings (Mtani & Mbuya, 2018).

4.3 Future Directions for this Research

This study has demonstrated a need for further inquiry on possible causation in multistorey building in Selangor however there are also needs of information in other areas besides examining occupant fire safety and evacuation preparedness. Furthermore, the more specific fire possible causations in commercial and residential multistorey buildings need to be carried out as well the comparison of fire evacuation preparedness among the different types of building occupants. Besides that, more experiment with a large number of evacuees in multistorey buildings should be carried out, which the result may help building safety designers and building occupants to have a better understanding on the possible causation of building fire and how to evacuate from the building. Finally, there is need for future research to measure the effectiveness of fire safety measure in multistorey building by make use of the existing understanding of fire possible causation and existing technologies in order to improve the efficiency of building occupants in building fire evacuation.

05.0 CONCLUSION

In conclusion, this research lists the top causes of fire outbreaks which consists of electrical faults/appliances, cooking, smoking, and poor maintenance of electrical appliances. Besides that, other possible causes of multistorey building fires include carelessness in fire handling, arson, matches or lighter, gas leaks, mosquito coil, spontaneous combustion, chemical reaction, and firecracker/firework. Furthermore, the methods that can be taken to reduce the possibility of fire in multistorey buildings include increasing awareness, increasing knowledge, improving guideline, using human sense, preparation of an emergency response team, proper maintenance, and precautionary measures.

Therefore, this research helps add new information to the existing body of knowledge on multistorey building emergency fire evacuation since there is still limited scholar resources on the study area, especially for mixed-use multistorey buildings. The limited number of knowledge resources is the main reason for doing this research, and the findings of this research may help establish issues plaguing multistorey building emergency fire evacuation. The findings of this research may be used by building occupants, designers, developers, property managers, staff working on/in community house, maintenance personnel, and local authorities, and it can also serve as a requirement or enforcement guide for the government. The study may also improve current research on the efficiency and cost effectiveness of building design and construction, and also provide a higher overall quality of life for the people who live and work in multistorey buildings.

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