STRATEGIES FOR PREVENTING FIRE IN HIGH-RISE RESIDENTIAL BUILDINGS

ANDREA VALERIE LAW

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2018

STRATEGIES FOR PREVENTING FIRE IN HIGH-RISE RESIDENTIAL BUILDINGS

ANDREA VALERIE LAW

RESEARCH PROJECT REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER SAFETY, HEALTH AND ENVIRONMENT, ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2018

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: Andrea Valerie Law

Matric No: KQD160028

Name of Degree: Master Safety, Health and Environment, Engineering

Title of ~~Project Paper~~/Research Report/~~Dissertation/Thesis~~ ("this Work"):

Strategies for Preventing Fire in High-Rise Residential Buildings

Field of Study: Safety, Health and Environment, Engineering

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate's Signature Date:

Subscribed and solemnly declared before,

Witness's Signature Date:

Name:

Designation:

STRATEGIES FOR PREVENTING FIRE IN HIGH-RISE RESIDENTIAL BUILDINGS

ABSTRACT

In this study, high-rise residential building is at high risk of fire and currently there are no comprehensive standards for fire prevention. High-rise residential buildings focus many challenges to prevent fires in term of fire protection facilities by building management, resident's involvement with building fire safety and the importance of fire prevention among residents. Therefore, the focus of this study is to develop strategies for fire prevention in high-rise residential buildings. There are two proposed strategies and checklist developed for building management and residents. Methods such as survey and benchmark are used in this study. The survey is distributed to expert's and as results, the opinion is used to priorities fire prevention implementation. Whereas, benchmark is used to develop strategies and guideline to manage fire protection system in the building. Then, a checklist is developed to ensure the strategies are practical and indirectly enhance fire prevention practices. The success of strategies and checklist implementation will able to give positive changes toward fire prevention in high-rise buildings. Since this strategy is developed based on expert's opinion and benchmark from other countries, in the future the study can be improve by high-rise residents and building management involvement to practice the strategies and response feedback for better implementation.

Keywords: Fire prevention, high-rise residential, expert's opinion, benchmark, proposed strategies, checklist.

STRATEGI UNTUK MENCEGAH KEBAKARAN DI BANGUNAN PANGSAPURI

ABSTRAK

Dalam kajian ini, bangunan pangsapuri mempunyai risiko kebakaran yang tinggi dan kini tiada piawaian menyeluruh untuk mencegah kebakaran. Bangunan pangsapuri menghadapi banyak cabaran untuk mencegah kebakaran dari segi kemudahan perlindungan kebakaran dengan pengurusan bangunan, penglibatan penduduk dengan keselamatan kebakaran dan kepentingan untuk mencegahan kebakaran di kalangan penduduk. Oleh itu, fokus kajian ini adalah untuk membangunkan strategi pencegahan kebakaran di bangunan pangsapuri. Terdapat dua strategi dan senarai semakan yang dihasilkan untuk pengurusan bangunan dan penduduk. Kaedah seperti soal selidik dan penandaarasan digunakan dalam kajian ini. Soal selidik diedarkan kepada pakar dan keputusan tersebut digunakan untuk pelaksanaan pencegahan kebakaran. Manakala penanda aras digunakan untuk membangunkan strategi dan garis panduan sistem perlindungan kebakaran di bangunan. Kemudian, senarai semak dibangunkan untuk memastikan strategi praktikal dan secara tidak langsung meningkatkan amalan pencegahan kebakaran. Keberkesanan strategi dan pelaksanaan senarai semak dapat memberi perubahan positif terhadap pencegahan kebakaran di bangunan pangsapuri. Oleh kerana strategi ini dihasilkan berdasarkan penghakiman pakar dan penanda aras dari negara-negara lain, kajian ini dapat ditingkatkan dengan penglibatan penduduk dan pengurusan bangunan untuk mengamalkan strategi yang telah dihasilkan dan maklum balas untuk pelaksanaan yang lebih baik.

Kata kunci: Pencegahan kebakaran, bangunan pangsapuri, pendapat pakar, cadangan strategi, senarai semak.

ACKNOWLEDGEMENTS

First of all, I would like to thank God for all the blessing that I received throughout this life. Thank you for hearing my prayers, bless my daily journey, keeping me perseverance and strength throughout this process. I also would like to thank God for all the beautiful people around me.

Secondly, I would like to thank my supervisor, Professor Ir. Dr. Abdul Aziz Bin Abdul Raman for keep pushing and giving encouragement to complete this research. Despite with Prof. tight scheduled, I never felt left out throughout this process. I will always remember all the motivational talk and knowledge that Prof. gives and I am lucky enough to have Prof. guidance since my first semester. I also wish that Faculty of Engineering will grow even further under Prof. direction.

This field of research is an interesting field to learn and I would like to dedicate my writing to my parent, Law Poh Kiong and Servia Lahok for instilling interest. Thank you for all the sacrifices that both of you have made for me. I never felt alone despite the distance that separated us. Thank you for all your support, encouragement and prayers that give me the strength to complete this Master Degree and I also would like to thank my brother, Aaron Bryan Law for keeping me motivated.

Not to forget, I would like to say thank you from the bottom of my heart to my course mate KGJ/KQD, college mates and friends for making my Master Degree an enjoyable and exciting experience despite the struggle and hassle that we face throughout our journey in the University of Malaya. Thank you for making my University life a memorable and I am in much regret for any mistakes that I have done towards all of you. My wishes for all of us is, best of luck in our next endeavour and hope we meet again.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

BAT	:	Best Available Technique
CO	:	Carbon Monoxide
CO_2	:	Carbon Dioxide
ERT	:	Emergency Response Team
GC	:	Gas Cylinder
SBO	:	Sarawak Building Ordinance
SIRIM	:	Standard and Industrial Research Institute of Malaysia
SPSS V20	:	Statistical Package for Social Science Version 20
UAE	:	Unites Arab Emirates
UBBL	:	Uniform Building by Law

LIST OF APPENDICES

CHAPTER 1:INTRODUCTION

1.1 Research Background

In this study, various strategies that can be used to prevent and manage the fire in high-rise residential buildings. These fire strategies are used to improve fire safety standards in Malaysia and make fires outbreaks in high-rise residential building less common cases. High-rise building in Malaysia is developing and it shows concerns about the effectiveness of the existing fire prevention strategies. There is an increase of at least 47 number of high-rise residential buildings in Malaysia and up to 10% cases involving high-rise buildings which have drawn intensify concern over the building fire prevention. London Grenfell Tower has an awakening called to urge all high-rise residential buildings to raise the standard on fire prevention. Both existing and new high-rise residential building need to raise their fire prevention standard. This is because high-rise residential buildings have increased in demand especially in developing the city. It is one of the most preferable residentials because of its facilities provided. Facilities provided complete such as the necessity of daily life such as a convenience store, swimming pool, gym and residential security.

High-rise residential buildings are at high risk when fire outbreaks. This is due to its height, multiple numbers of occupancy, fire load, delay in time for evacuation and fire spread faster in vertical positions. Lack of exposure and information to prevent fire will make it worst. Residents and buildings management need to work together in order to prevent fire. The fire safety management plan should be effective and efficient to prevent fires from reoccurrence. The main issue comes from effectiveness and efficiencies of building management. Fire safety equipment such as passive and active fire devices need to be properly managed and maintained in order to make sure it functions during emergency outbreaks in the buildings (Abd-Wahab et al., 2015). Besides that, fire safety

management needs to involve all residents to be safety committee and responsible to make sure fire prevention implementation is successful. The objectives of this study are to provide strategies and checklist among high-rise residential buildings management and residents. Proposed strategies are based on expert's opinion and based on Singapore and Hong Kong fire safety practice. Then, checklist is developed based on proposed strategies which able to help to manage high-rise residential buildings and provides proper implementation regarding fire prevention in the buildings.

1.2 Problem Statement

Fire is always being a major cause of damage to property, injury, and loss of life. Fire and smoke within enclosed places such as in residential buildings are able to give bigger threats to residents. High-rise residentials is full of occupancy with varies ages, health condition, and fitness level. high-rise residential buildings. Currently, there are no comprehensive guidelines on these strategies can be implemented in high-rise building by various parties, including the residents. Therefore, in this study, a literature is being review based on guideline and the respective checklist will be developed for existing high-rise building. These strategies will able to save more life possible and minimise property damage. Fire should be prevented by implementing appropriate safety measures, early detection, and control system during an emergency. These include prevention, control, and other mitigative strategies. All high-rise residential buildings should be designed and provided with an appropriate level of safety measures comply with fire safety and legislative requirements. The focus of this study is to prevent fire at an early stage and instil resident safety awareness. Strategies and checklist will be developed to improve current practices on fire prevention and reduce common causes of fire outbreaks.

1.3 Research Questions

To develop strategies for preventing fires, researchers are concerned towards;

i. What are the strategies that can be used to prevent fire in existing high-rise buildings?
ii. What are expert's opinion to improve fire prevention in high-rise residential buildings?

1.4 Research Aim

To provide proposed strategies and checklist that are able to guide and educate residents and buildings management to practice fire prevention in high-rise residential buildings.

1.5 Research Objective

The objectives of this study are;

i. To analyse expert's opinion on fire prevention checklist proposed for high-rise residential.
ii. To identify strategies that can be used to prevent high-rise residential building fires based on current practices.
iii. To develop a checklist for high-rise residential buildings.

1.6 Research Scope

In this study, the scope is covered only for;

i. High-rise residential building above 18 meters height or roughly about 6 storeys.
ii. Target of the study are high-rise residential buildings.
iii. Fire prevention for high-rise residential buildings only.

1.7 Report Outline

a. Chapter 1: Introduction

This chapter is to introduce research background, problem statement and research questions. The overall of this study is to achieve research objectives which are to analyse expert's opinion, identify strategies and checklist that can be used by building management and resident to prevent fire. This study is only to prevent fire in high-rise residential buildings and above 18meters height or about 6 storeys only.

b. Chapter 2: Literature Review

In this chapter, the focus is highlighted on the topic to achieve objectives of the study. Highlighted topics are such as common causes of fire outbreaks in the high-rise building and residential building, strategies implement to prevent fires, Law, and regulation used and issues arise in preventing fires and managing high-rise residential buildings. Thoroughly reading similar study is able to develop proposed strategies based on other countries that already established in managing high-rise residential buildings.

c. Chapter 3: Methodology

The methodology is constructed to find a better solution to solve the problem in high-rise residential buildings. The method used is by distributing proposed action checklist to expert’s panel and by adopting implementation of fire safety strategies from Singapore and Hong Kong. The methods are to ensure the research objectives are achieved.

d. Chapter 4: Results and Discussion

This chapter consists of result and discussion of analysis based on constructed methodology. Proposed strategies are analysed and develop based on survey and benchmark from other countries. The outcomes of the analysis are by categories priorities of implementation and adapting Singapore and Hong Kong fire safety implementation. Then, a checklist for residents is developed. The results are further discussed in this chapter.

e. Chapter 5: Conclusion and Recommendation

In this chapter, it is concluded that the research objective is achievable by developed strategies based on expert's opinion and adapting Singapore and Hong Kong fire safety practices while checklist is to ensure resident is educated and proposed strategies are implemented. Therefore, recommendation for future study is to keep revise and update the proposed strategies and checklist. Feedback regarding the proposed strategies and checklist should be collected in the future to enhance its effectiveness.

CHAPTER 2:LITERATURE REVIEW

2.1 Fire Hazards in Residential Areas

Fire hazard is related to fire load, occupancy, building material and firefighting equipment. Meaning of fire hazard is by any alteration that causes difficulties to escape, difficult to escape in a crowded area, removal or not present of fire safety equipment in the building, firefighting equipment not in good conditions, inadequate egress of the buildings and any circumstances that can increase the danger to life. Therefore, firefighting equipment is used to extinguished, prevent, give warning, provide adequate access to escape, provide direction, provide emergency light and provide power supply upon fire outbreaks (Bakar, 2006).

Fire hazards are easily found in residential due to lack of enforcement to control fire hazard and implementation firefighting equipment. Lack of fire safety awareness among residents are also considered as the fire hazard . Fire automatic such as sprinkler system does not properly functioning also considered as the fire hazard (Rashid et al., 2012). Obstacles such as furniture and architecture design in the building would cause fire hazard because contribute to delay in time for evacuation (Oven & Cakici, 2009). Most of the Malaysian residents are aware of fire prevention and have basic knowledge but depending on self-awareness factors.

This factor is measured based on human factor more than engineering factor. A study has been conducted over 286 residents and figure 2.1 shows the majority of residents does not own or install fire safety equipment such as portable fire extinguisher, smoke and heat detector at homes. Whereas only 13.3% of the residents have basic fire equipment installed at their homes. This clearly shows that residents are not aware of the importance

of having fire safety appliances at their home and lack of precautionary action on fire safety.

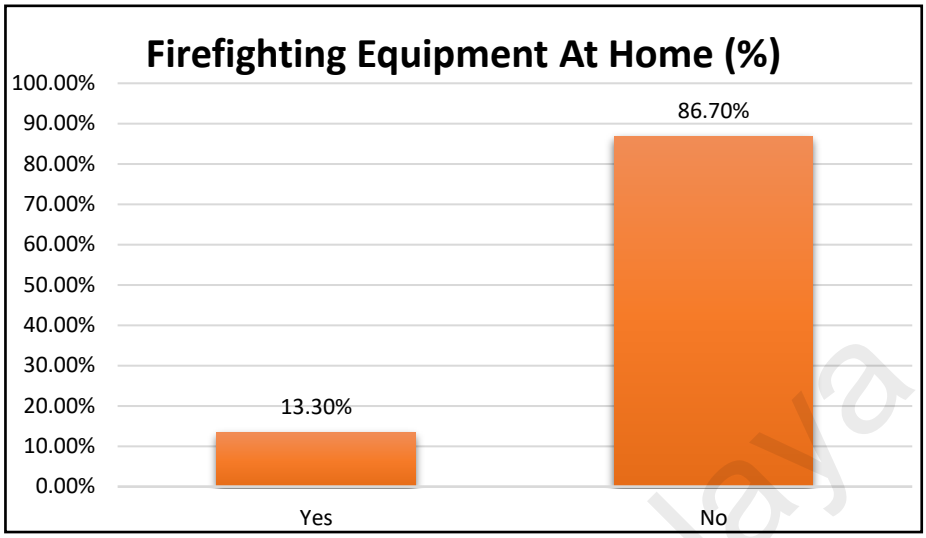

Figure 2.1: Firefighting equipment at home

Source: Rashid et al., 2012

Due to high responses on not having firefighting equipment at homes, figure 2.2 shows several reasons on why residents choose for not having firefighting equipment at home. Percentage of 64.5% residents never thought of having firefighting equipment at their homes has shown that residents are ignorant of the importance of having the appliances at home. Besides that, 12.9% of the residents responds that they never been exposed to any fire safety campaign while 9.7% of the residents do not think that it is necessary to have firefighting equipment at home. This has shown ignorant behaviour among the residents on firefighting equipment. Datuk Soh Chai Hock, a retired Director General Fire and Rescue Department Malaysia has urged home residents to install fire detectors and portable fire extinguishers for their household safety because prevention is the cheapest and effective way to prevent fire (Nation, 2017). There is no doubt that, purchasing firefighting equipment could be an additional investment but it is for a good cause. 11.3% of residents respond that purchasing firefighting equipment is beyond financial necessity and 1.6% has respond to other opinion.

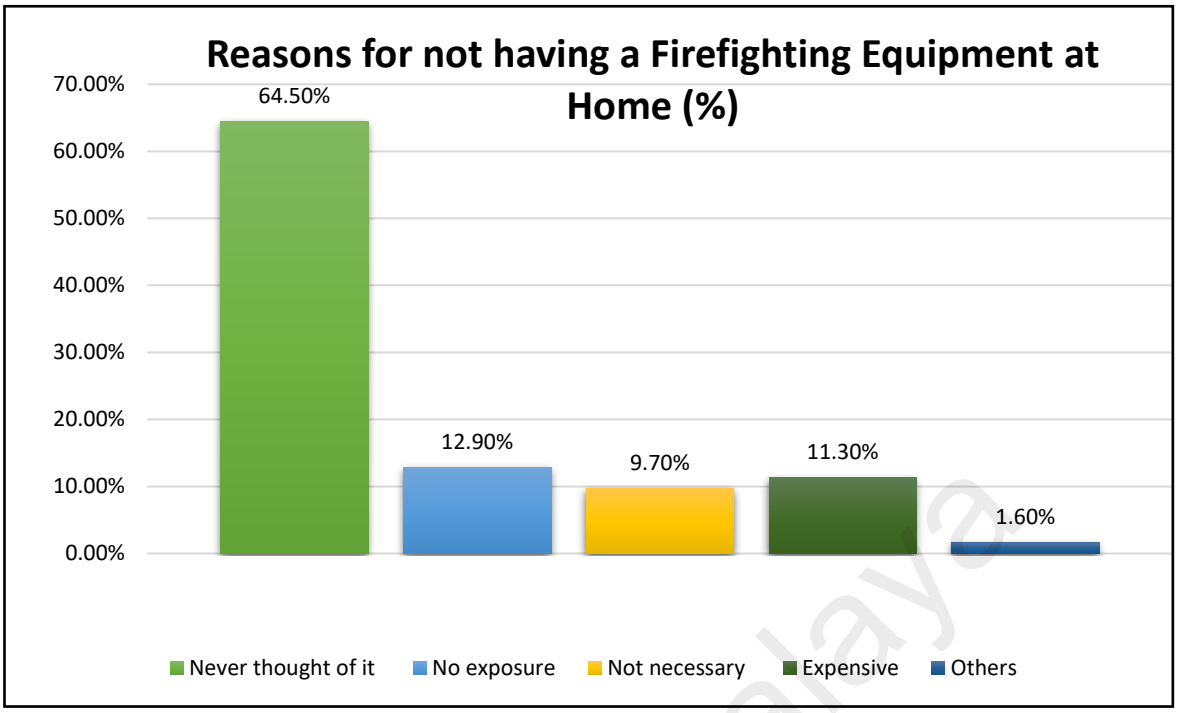

Figure 2.2: Reasons not to have firefighting equipment at home

Source: Rashid et al., 2012

Most of the residents also not aware that fire hazard also can be in form of material and source of heat energy. Materials that usually found in residential is such as wood, liquids, textiles, gas, and plastics are the source of fire hazard. All of these substances are flammable and combustible. Sources of heat such as electrical appliances used, cooking appliances, lighter or matches, candle, lightning, fireworks, friction and also glowing fire such as cigarette and mosquito coil (Kamaruzzaman et al., 2016).

Other than that, house appliance such as house iron grilled has to turned into hazard towards residents due to several trapped incidents. Recently, there are few cases in Malaysia related to resident trap in their own house because of trapped by iron grilles. Grilles are initially installed to prevent break-in by robbery but turn into a residential nightmare when fire outbreaks. There are few cases that happened in Malaysia residents where they are trapped in the house during fire outbreak. Iron grilled has become the fire hazard due to unable to safe life of the house owner.

2.2 Causes of Fire in Residential Area.

Residential fire outbreak can be from many sources. Based on a study, the most common residential fires are from electrical appliances failure. The electrical failures such as short circuit, overloaded electricity on electrical distribution or electrical appliances and also from heating resistance (Kamaruzzaman et al., 2016). Whereas in other studies, cooking equipment is the leading cause of fire outbreak by 87% followed by intentional, smoking material, heating equipment then electrical and lighting distribution. Statistically recorded in 2011 until 2015, 3650 fires involving cooking equipment. Cooking equipment such as cooktop fires, microwave oven and also portable cooking (Campbell, 2017). National Fire Protection Association (NPFA) survey also shows cooking equipment is the leading cause for high- rise building to cause the fire then followed by electrical, smoking materials, intentionally arson, heating equipment, and lighting equipment and candles (Ahrens, 2016).

Then, human negligence such as unattended cooking, leaking gas and unaware of combustible material close towards heat source has contributed to causes of fires (Kamaruzzaman et al., 2016). Back in 2008, causes of fire can cause death. Investigation finds out that, 78% of fire outbreaks are caused by unintentional fire, followed by 41% fire caused by cigarette as a source of ignitions (Chien & Wu, 2008). In Dubai, causes of fire outbreak in residential are incidents such as electrical malfunctions, gas leak and from cooking equipment (Alqassim & Daeid, 2014).

There are also minor causes of fire outbreak from an irresponsible person, intentionally arson, unconscious person which under drugs, alcohol or mental illness (Kamaruzzaman et al., 2016). On 14th September 2017, fire outbreak has killed 21 students and 2 teachers in the school building. Investigation showed that fire was started by irresponsible teenagers who wanted to take revenge and were under influence of drugs (Hariz Mohd & Ying, 2017).

2.3 Definition of High-Rise Building

There is a various definition on high-rise building which is a structure that has floor, walls, roof and also windows. It also consists of many occupants and depends on the elevator to reach their floor. Other than that, high-rise building can be a building that will cause major impact during emergency evacuations, the buildings that has seven storeys and above and buildings that exceeds fire-fighting equipment (Craighead, 2009). It is not possible to define high-rise building just by its heights but it also should be depending on the environment surrounding and uses of the building. From the structural view, high-rise building can be defined as buildings that are affected by nature sources such as wind or earthquakes. Height can varied depends on the functions of the building such as residential, administrative or hotel (Shams, 2011).

Some researchers defined high-rise building as in eight storeys above. This description is included compartment floor, stability needs in a long period, rescue is not possible from outside, evacuation will take times, sprinkle, fire-fighting is difficult from inside and also having phased of evacuation strategy (Butterworth, 2013). Based on NFPA, high-rise building must have automatic fire protection devices and defined high-rise building as seven storeys and above ground (Ahrens, 2016). Whereas in Hong Kong, high-rise building is building that exceeds 30 meters based on their Fire Service Installation Code. While China defined high-rise building that has to exceeded 24 meters above ground (Chow et al., 2013)

In Malaysia, practices used for building safety is Uniform Building by Law (UBBL). Building with the topmost floor which is more than 18 meters should be provided with access to firefighting such as firefighting lobbies, firefighting staircase, fire lifts and fire safety system. By ten storeys above ground or above 30 meters, the building must be equipped with a hose reel or automatic sprinklers (Laws Ordinance, 2008). Above 30 meters is the level where fire appliances limit access level (Wong, 2016). Therefore, for

this study, high-rise residential buildings above 18 meters height or roughly about 6 storeys will be evaluated due to difficult access for firefighters during emergencies above the height. Besides that, the high-rise residentials is sleeping risk compared to other high-rise building functions.

2.4 High-Rise Building Fire

High-rise building is more likely to have fire prevention because it is more high risk compared to non-high-rise buildings (Ahrens, 2016). The consequences and probability are higher (Richardson, 2013). Expert's opinion is necessary when high-rise building is at high risk of fire outbreak. This includes new and existing high-rise building (Yau & Ho, 2014). Based on a study conducted, leading areas for the fire to outbreaks is from the kitchen or cooking area followed by bedroom, trash chute and living room (Ahrens, 2016; Campbell, 2017).

Fire in high-rise building is categorised as i) fire quickly spreads. Fire will quickly spread when fire separation is not arranged properly. This is because the fire will easily react towards combustible materials. Fire is quickly spread and in high intensity. Based on air convection, initial horizontal velocity is able to diffuse for 0.3m/s while in high velocity the fire can reach up to 3m/s until 4m/s. The vertical velocity of fire also able to spread 10 times faster than horizontal velocity. ii) Challenge to put out the fire. It is challenging to put out the fire for the high-rise building. This is because fire has to be put out from the outside because of the height of the building.

Fire in high-rise building such as residential, hotel, dormitories and office usually occurred at height of above 6 storeys (Ahrens, 2016). Therefore, it is more challenging to put out the fire in high-rise building because of the thermal heat in the building, fire spreading faster and inadequate fire safety equipment installed. iii) Difficulties for

evacuation. High-rise fire will cause more time for evacuation due to its height. Occupancy will be facing difficulties to reach the safe floor. Lack awareness of fire safety has increased the time to evacuate as the travel distance is longer compared to a low building. Fire in high-rise building also takes time to put out as the fire load is heavy. (Ma & Guo, 2012).

In a high-rise building, there are a various different type of materials such as furniture, appliances, kitchen cleaning chemical, semi-finished material, raw materials and other resident's daily needs. All of the materials if caught in the fire will rapidly spread and produce poisonous smoke. Poisonous smoke is able to cause difficulties in breathing, severe headache and fatal if high concentration. Evacuation during an emergency will be difficult. (Yang, 2013).

2.5 Case Study Related to Fire Hazards

Varies population and functions under one building gives a great amount of fire hazard. Building material, furniture, fuel usage, electrical usage and functionality of the building are the hazard and ability to cause fire outbreak. Fault tree analysis is one effective method that used to figure out fire hazard in the building. This case study is to analyse and evaluate fire safety system in the building. It is an advantage to fire safety management to identify causes of fire and how to mitigate from reoccurring. Besides that, this method able to prevent fire analysed fire process and identify the cause of the outbreak (Hu, 2016). In China, statistically shown that 295 hotel building has caught on fire from 2006 until 2015.

Based on an investigation, main fire hazard that leads towards fires in a hotel is from personnel's unsafe behaviour, flammable and combustible substance, faulty on electrical equipment, wiring faulty, mismanagement of fire prevention and other fires outbreaks.

This case study has concluded that possibilities of each fire hazard are able to be avoided by implement control measures and controlled by human efforts. Fire can be prevented by implemented proper control measures. Besides that, possibilities of mismanagement of fire prevention need to take serious action. This is because most of the fire outbreak is from lack of fire management where fire control regulation and not proper implementation (Hu, 2016).

Another case study shows hazard of fire is due to fire development and firefighting faulty. Development of fire is considered as a hazard when it is not handled properly such as malfunction automatic extinguishing system and fire is not extinguished properly by personnel. Whereas firefighting faulty is part of fire hazard due to the delay of fire alarm, inadequate fire equipment, lack of firefighting skills, and difficulties to fight the fire. By conducting fault tree analysis, it shows that fire control and firefighting plays an important role. The effectiveness of firefighting are able to strengthen by improving the accuracy of alarm detection, improve fire training and encourage self- help extinguishment to minimise spreading of fire (Haitao et al., 2012).

Fire safety building is related between interfaces of system and personnel in the building. The existence of defect needs to be identified and improved in order to prevent fire. High-rise fires are at high risk of loss of life and property. Analyses of fire hazard in fault tree method are used to find the default of precautionary system and indirectly help during an emergency. In this case study, exposed to fire scene is the fire hazard because of a defect in alarm, defect in structure control, defects in extinguishing and defects in the evacuation of control measure (Liu et al., 2012).

2.6 General Fire Prevention Strategies

Fire is able to cause loss of life, damages towards properties, psychology disturb, effect surrounding environment and also affect the economy. To prevent fire outbreaks, fire safety management is one of the strategies. Fire safety management serves as a framework to promote fire prevention. Management procedures are able to implemented and any improvements will take place to enhance effectiveness to prevent the occurrence of fire and when it does happen, all appropriate fire safety systems are activated (Baker et al., 2013). Fire safety management also a strategy used to improve building operation (Wong & Xie, 2014). Fire safety management needs to have a proper management plan. Fire management plan should consist action and procedures to minimize fire outbreaks and to protect the life of building occupancy. The objectives of fire management are to ensure all parties aware of their roles and responsibilities on fire safety, identified fire prevention activities, clear emergency procedures to make sure safe evacuation and maintenance of fire installation to control the fire from spreading. Fire management plans is categorized into three components as shown in figure 2.3.

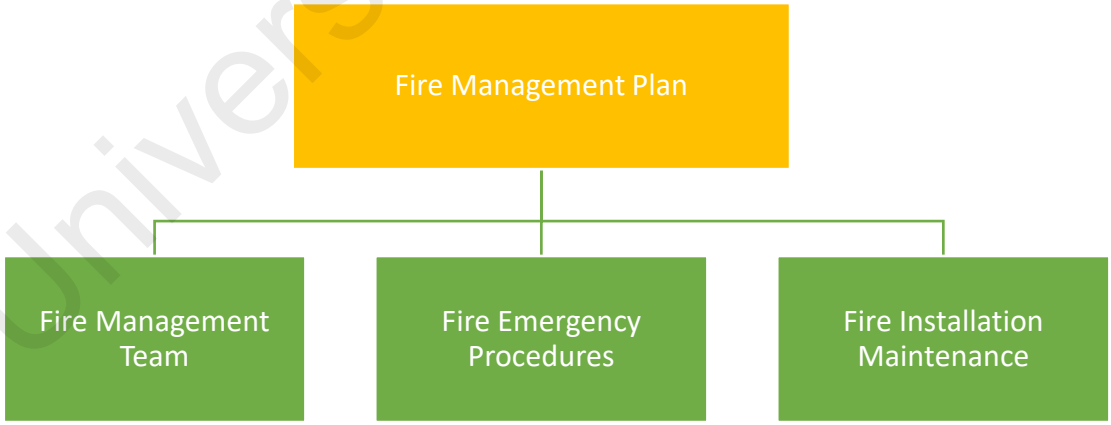

Figure 2.3: Components of fire management plan

Source: Wong & Xie, 2014

Fire management team is the team that responds to control situation during operation and within planning to deal with incidents of emergencies This is to make sure that team

member understands clearly their roles and responsibilities in the implementation of fire safety. The management team consists of fire safety director, fire safety managers, senior fire wardens and staff on the ground. Each member of the team carried different responsibilities and roles. Table 2.1 is the list of management team responsibilities.

Table 2.1: Management team responsibilities

Management Team	**Responsibilities**
Fire Safety Director	• Set fire safety policy, objectives and plan for budget. • Leader of the team. • Take charge when fire emergency for evacuation of occupants, lead response team and liaise with fire department.
Fire Safety Managers	• Perform planning and organize staff training. • Planning and organize for building work manual or procedures and maintenance. • Planning and organize safety and security of fire emergency and special events.
Senior Fire Warden	• Implement staff training. • Implement maintenance and buildings works. • Implement of fire emergency procedures.
Staff on Ground	• Perform fire prevention and perform regular checking on evacuation routes and report on blocked or broken signage. • Validate fire by investigating cause of alarm and supervise evacuation by directing occupants' evacuation routes and assist occupants.

Source: Wong & Xie, 2014

Fire emergency responses is part of fire safety management plan because it holds the key roles and action in fire investigation and evacuation process. Fire action plan is the term to define the process and the plan will assist occupancy safety during an emergency. Fire action plan consists of fire control centre, fire control, evacuation control and crowd

control. Fire control centre is a room that gives provisional towards automatic alarm system. This control centre will receive information and support towards emergency response centre. Staff working in this control centre are responsible to monitor and identify the location of the fire, investigate firefighting measures, informed responsible team and brief fire department upon arrival on the outbreaks. Staff working under fire control centre are performing the responsibility on fire control. Fire is either detected by automatic detection system or by a person in the building. If the fire is detected by staff, an action such as activated nearest fire alarm system, inform fire control centre on the fire, put out the fire by using appropriate fire equipment and leave the area if fire spread (Wong & Xie, 2014).

Other than that, evacuation control also part of fire action plan. Evacuations are managed by fire control centre. Fire investigation is required to verify the incident and building evacuation that takes place after being directed by fire safety director. Fire safety director has the authority to control the operation of security staff or control centre staff as appropriate. Once the fire alarm is activated, evacuation of occupancy takes place. Fire warden and security staff play an important role to navigate occupancy to safe evacuation routes. It is a challenge when fire outbreaks in a shopping mall or multipurpose building because some occupancy might not be familiarized with fire evacuation. Therefore, assembly point is needed in this plan. Operation and management fire safety team needs to make a suitable plan to control the crowd such as includes authorities such as Fire Department and Police Department, identified early sign and potential mitigation measures to overcome the overcrowded areas, provide more trained staffs, improve public announcement and control road traffic.

Last plan in fire management is fire installation maintenance. Fire safety in building plays a part in fire safety strategy (Wong & Xie, 2014). Fire safety systems can be active and passive fire protection system. Based on a study was done, active fire protection

system are such as hose reel, sprinkler, heat and smoke detector, break-glass and fire panel system, portable fire extinguisher, fire lift, exit signage and also emergency lighting (Othuman Mydin et al., 2014). Table 2.2 is the list of active fire protection functions.

Table 2.2: Active fire protection functions

Active Fire Protection System	**Functions**
Hose reel	Provided in every floor exceeding 18 meters height building. It provides water supply to combat fire and usually located at exit route and lobby lift.
Sprinkler	Release water automatically to minimize spreading of fire and extinguish the fire source. The building above the height of 18 meters needs to install sprinkler.
Heat detector	Operates automatically once heat is detected from fire sources. This will activate fire alarm and give warning occupant to evacuate.
Smoke detector	It indicated fire outbreak in the building and activate the fire alarm. Normally it is installed in a room with a high risk of fire such as switchboard room. It also used for maintenance personnel in case fire outbreak while performing maintenance.
Break-glass	The alarm will be manually operated once occupant breaks the glass due to fire outbreak. Need to be installed at the entrance and escape route of the building.
Fire panel	Located at the ground of the d floor of the building and used for firefighters to identify the exact location of the fire. Particular zone of the indicator will lighted up when fire outbreaks.
Portable fire extinguisher	Is an agent to cool down burning fuel, remove oxygen or stopping chemical reactions. It is located near to exit routes so that occupant can easily use to fight the fire.
Fire lift	Provided in every 18 meters height building and used to transport firefighter during an emergency.
Exit signage	This is used to notify occupants routes of exits. It is an effective tool for evacuations.

Emergency lighting	This lighting is used to allow safe evacuation in the building. It is activated when electrical supplies in the building fail.

Source: Othuman Mydin et al., 2014

Passive fire protections are compartment wall and fire door. Compartment walls is used to minimize spreading of smoke and fire. It is very useful for firefighters to control and extinguish the fire because compartment is able to minimize spreading of fire to another compartment. Whereas fire door is able to protect the occupant from escape heat and smoke. Besides that, fire door functions also for evacuation routes and fire door should always be kept closed but unlocked (Othuman Mydin et al., 2014).

Operation and maintenance manager is responsible to decide on maintenance plan on fire safety system. The maintenance plan should be reviewed regularly and included maintenance passive and active system and alterations Maintenance on fire safety installation should be tested individually to make sure the system is operated properly during an emergency. The installation also needs to complied with code and standard of fire protection system. The alteration can be carried out from time to time for building improvement works. The alteration is based on updated information regarding maintenance of the procedures and record as shown in table 2.3. Staff should be informed and trained accordingly to the alteration. The alteration may influence by a potential increase in fire load over time, temporary disruption on operations of fire safety systems, temporary suspension of escape route, hot works and a false alarm on the detection system.

Table 2.3: Maintenance information

Maintenance Records	**Maintenance Procedures**
• Manufacturer's details	• The responsibilities of technical services staff in arranging for an

• Details on the function/purpose/location of the system in the building • Date of installation • Reference numbers/batch codes of the parts • Dates of all scheduled maintenance and person carrying out the maintenance • Report on any parts replaced and status of the system • Report of faults • Alteration works on the system	ensuring the maintenance of the systems • Daily checking procedures on the operation of the systems • Procedures for temporary shutdown/isolation of the system • Procedures in reporting fault on system, and checking works of the contractor • Dealing with the initiation of the system – a real fire or a false alarm • Procedures for reinstating the system • Recording and filing of information

Source: Wong & Xie, 2014

Besides that, good housekeeping also part of the strategy to prevent fire. Building management shall ensure that rubbish is not accumulated and illegally loaded with combustible materials as this will be harmful to building functions and residents. A separate room shall be provided for housekeeping utilities. All rubbish shall be removed from the premises daily and not be stored. There shall be designated smoking areas, including spaces for staff smoking. There shall be designated smoking areas, including spaces for staff smoking. In these smoking areas, there will be a provision of ashtrays or similar to avoid random discarding of cigarette butts. Ashtrays shall be regularly emptied and contents will not be disposed with general rubbish. All internal areas shall be non-smoking areas. Other than that, all electrical appliances in the buildings shall be tested on a regular basis, as recommended by the manufacturer of the product in order to ensure the potential ignition risk due to faulty appliances is mitigated (Wong & Xie, 2014).

2.7 Fire Prevention in Residential Buildings

Fire preventions is measured based on the impact of the probability or consequences of fire and ability to reduce it in the future. Figure 2.4 shows fire prevention measures in order and this measure starts with prevention of fire ignition. At this phase, the residents need to be educated by safety precaution on the danger of small ignition such as cigarettes or matches in the residential building. Any smoking materials should not be allowed in the residential building. This is because fatality due to cigarette is higher (Runefors et al., 2017). In China, the number of death from the residential building has been decreased after the implementation of 'No Smoking' material in the residential building (Xin & Huang, 2013). This initiative should be taken from management and the residents. Besides that, initial fire control such as equipped each resident unit with fire extinguishers will able to prevent the fire from spreading (Ma & Guo, 2012).

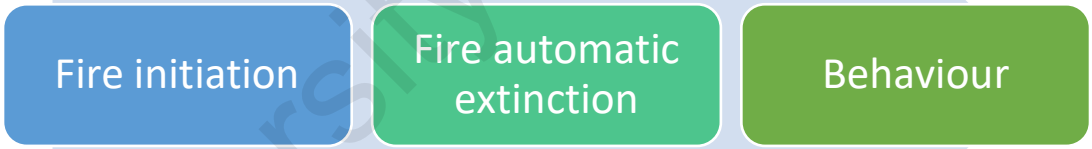

Figure 2.4: Fire prevention measures

Source: Xin & Huang, 2013

Inspection and maintenance of automatic devices are vital. Regularly performed inspection and maintenance is a good practice. This is to make sure the devices are working properly and reliable during an emergency. Fire protection devices normally installed at high-rise residential building are smoke exhaust system, sprinkler system, fire alarm, heat and smoke detector. In D.R. Kimberly and J.R. Hall research, it is proven that sprinkler can reduce death in high-rise residential building compare to building that has

none (Xin & Huang, 2013). This shows that sprinklers system can reduce the impact of consequences of fire by controlling heat from the fire. Smoke detectors and education exposure are also suitable to prevent fires (Smith et al., 2007). The smoke detector is very useful to be installed in residents because this will able to alert elderly to emergencies (Runefors et al., 2017). Besides that, residents also need to be equipped with fire blanket in order to prevent the fire from spreading (Stumpf et al., 2017). In Dubai, it is mandatory for each residence to be equipped with fire safety devices (E & Zhou, 2016)

Another fire prevention measure is a behaviour of the residents which is during evacuations. Evacuation practices such as fire drill and information on access and egress from the building. Besides that, this strategy will able to give correct information to fire department for their record and extinguishment efforts. A study shows that fire drill performed every once in three years are able to achieve 91% of no victims (Xin & Huang, 2013). This action is important because if fire unable to prevent, residents need to be alert and prepared for evacuations.

In Taipei, Fire Safety experts has come out with strategies to ensure fire in residential is able to be prevented. For best expert consolidation, around 5 to 20 experts opinion is selected (Baker et al., 2013). The strategies are such as perform initial fire prevention analysis, implement fire escape plan, encourages residents to install fire alarm system, instil residents behaviours on the usage of fires and electrical equipment and improvise grille installation for easy escape (Chien & Wu, 2008). In Hong Kong, their fire safety concerns are by fire detection and alarm system. Fire alarm should be alert the whole building and alert messages will convey to not affected floor. Besides that, Hong Kong has implemented refuge floors for the high-rise building. This is to make sure occupants are able to reach the safe floor (Chow et al., 2013).

2.8 Fire Prevention Strategies in High-Rise Buildings

Based on analysis that has been done by Haitao et al. (2012), strategy to prevent fire in the high-rise buildings can be divided into strategies such as safety in technology and in management. These two strategies are used to minimise the occurrence of fire and indirectly improve safety performance. Safety in technology is referred to malfunction auto extinguish system, inadequate auto-alarm system, and inadequate fire equipment. This system is related to security and can be solved by installing sprinkler system, automatic alarm system, adequate fire, and rescue equipment. Improvement in detection and control should be informed to local government and fire department to make sure installation of equipment meet fire and rescue regulations. Effectiveness in safety management is used to improve negligence of duty delay in alarm and lack of firefighting skills. The problem can be solved by strictly implementing fire safety rules and regulations. Personnel carelessness and alarm detention are able to minimise. In order to improve firefighting skill for high-rise building, fire and rescue department can improve their tactical training and form detection system of fire equipment functions to ensure effectiveness during operations (Haitao et al., 2012).

High-rise fire safety is more concern towards preventing fire form outbreaks and control losses. Strategies to prevent the fire is a combination of firefighting equipment with technology. Building fire system is the interaction of technology of fire prevention, fire safety management and time. Provided with correct plan, organization, coordination, supervision and adequate firefighting will provide better coverage of building safety. Provided with effective technology, fire safety in the building is able to improve safety management in order to control and minimise fire hazard (Liu et al., 2012).

Initially, develop a fire safety management is to make sure strategy are planned well and able to achieve the objective. Management is able to conduct fire safety activities such as education and training. From there, fire safety operation is enhanced. Then,

investigate time phase for the building because each building has different time phase such as the design of the building, types of fire prevention and communication needed to transfer any emergencies. Next, technology is applied in order to make sure the fire prevention system is effective and efficient (Liu et al., 2012). This can conclude that management is the outline to create a strategy to prevent fire while technology is the method to be applied to the system of firefighting. Therefore, guidelines to create a strategy to prevent fire are such as;

i. Improve firefighting system.
ii. Strengthen the interaction between time, fire safety management, and technology.
iii. Appoint relevant personnel safety management and training.
iv. Reliable fire emergency plan.
v. Comply to fire protection rules and regulations.
vi. Enforcement

Other than that, there is some research developed fire prevention strategies by adapting from countries strategies. For example, China has adapted to Dubai fire safety implementation and used it as current fire prevention (E & Zhou, 2016). Safety strategies that can be considered are standards and quality of fire safety implemented, safety awareness practices and facilities maintenance. For this study, Malaysia is able to adopt Singapore and Hong Kong fire safety since because both countries has the most population in high-rise residential building with low risk of fire outbreaks (Ali & Chen, 2018). Both countries emphasise on fire management system and fire safety system to prevent fire in high-rise residential buildings. (SCDF, 2013; Yau & Ho, 2014). Table 2.4 describes strategies for building management in order to manage the effectively implement fire prevention. In both countries, a competent person should be appointed to carry out inspections. Recommendation or maintenance should be reported to safety

committee and documented. Authorities should be informed of any doubt regarding uncertainty on safety.

Table 2.4: Strategies building management in Singapore and Hong Kong

Singapore	Hong Kong
• Remove fire hazards in the buildings • Coordinate and supervise residents during evacuation • Staff is trained to ensure effective emergency response actions during emergency • Develop fire evacuation procedures • Supervise maintenance works in the building • Perform daily fire safety inspection • Fire prevention checklist is provided to residents • Fire standard in the building is maintained	• Documenting the period of inspections, testing and replacement, as appropriate • Documenting all fire safety provisions within the building • Checking the record keeping of maintenance actions • Checking that the actions in fire safety management plan are undertaken • Checking the period of maintenance and repairs • Authority is allowed to check any relevant documentation when required.

Source: SCDF, 2013; Yau & Ho, 2014

Besides that, both countries emphasize on implementing fire prevention measures such as passive and active fire safety system. This system is installed in the building due to high-risk of fire outbreaks. High-rise residential is at high-risk of fire and considering there is sleeping risk. Fire safety system from Hong Kong and Singapore is adapted because both countries have reduced the risk of fire outbreaks. This achievement can be a benchmark for Malaysia to improve the standard in preventing fires for high-rise residential buildings. Table 2.5 is a list of fire safety that is used by these countries.

Table 2.5: Fire safety system implementation in Singapore and Hong Kong

Fire Safety System	Hong Kong	Singapore
Passive Fire Safety System		
Means of escape	x	x
Means of Access	x	x
Fire resistance construction	x	x
Active fire safety system		
Audio/visual advisory system		x
Automatic actuating devices		x
Emergency generator	x	
Emergency lighting	x	x
Exit sign	x	x
Fire alarm system	x	x
Fire hydrant/hose reel system	x	x
Fireman's lift	x	x
Fire-fighting and rescue staircase		x
Fire control system		x
Fire detection system		x
Portable hand operated appliances	x	x
Pressurization staircase		x
Sprinkler system		x
Static or dynamic smoke extraction system		x
Ventilation/ air conditioning control system		x

Source: SCDF, 2013; Yau & Ho, 2014

2.9 Fire Act and Regulation in Malaysia

In Malaysia, there are Fire Act and Regulation to ensure building safety and the system is maintained properly such as Fire Services Act 1988, Uniform Building By-Law 1984 and Sarawak Building Ordinance 1994.

2.9.1 Fire Services Act 1988

This Act is used to provide efficient and effective fire protection of person and also property. For building services, it is important to understand the term of fire hazard, fire-fighting equipment, owner, fire certificates, premises and designated premises. (Refer table 2.6). This is a standard that Fire and Rescue Officer concern in order for building management to comply with Fire Services Act.

Table 2.6: Fire services important terms

Term	Descriptions
Fire Hazard	Any alteration and an overly crowded area which cause difficulties to escape from fire, any removal or not provided fire-fighting equipment in the building, inefficient fire-fighting equipment, inadequate exit and increases the occurrence of fire outbreak which causes difficulties to Fire and Rescue Officer to fight the fire.
Fire-Fighting Equipment	Provide warning towards the fire, prevent and extinguishes the fire, provide safe access to fight the fire, provide emergency lighting and power supply and direct safe routes to escape the fire.
Owner	Registered proprietor of the premises, or agent or legal representatives or person who receive rent from premises.
Fire Certificates	To make sure premises fire-fighting equipment is maintained at all times.
Premises	Types of building and for this research is high-rise residential building above 18 meters or 6 storeys.
Designated Premises	Based on size, used and location of premises. For this research, high-rise residential building in Malaysia which is 6 storeys and above.

Source: Law, 2009

2.9.2 Uniform Building By-Law 1984

Uniform Building By-Law (UBBL) is a documented safety standard and gazetted by the government. UBBL is used nationwide in Malaysia in order to prevent fire, safety programs and standard to be compiled with building management. UBBL is particular fire detection, fire alarm, and fire extinguishment. Fire requirements is fulfilled based on building designation of purpose group. For this study, the purpose group is under apartment and flat height of 18 meters or 6 storeys above. Under UBBL, the buildings need to fulfil at least minimum fire requirement. The building is advisable to have portable fire extinguishers for a private home unit and smoke detector at staircase area. Other than that, table 2.7 is other fire requirement needed.

Table 2.7: Fire requirement

Fire Alarm and Fire Detection	1. Manual electric fire alarm system 2. Automatic fire detectors 3. Centralized monitoring system 4. Fire command centre
Extinguishment System	1. Hose reel system 2. Sprinkler system

Source: Wong See Foong, 2016

2.9.3 Sarawak Building Ordinance 1994

Sarawak Building Ordinance (SBO) is only used in Sarawak because the Laws control on land matters. This Law is similar to UBBL implementation. For this study, SBO is more concerned towards extinguishing and detect fire, fire alarm and also exit sign with illumination. Table 2.8 is for modified dwelling height of 6 storeys above.

Table 2.8: Requirement high-rise building height of 6 storeys above

Extinguish System	A — Automatic Sprinklers. B — Water Spray System.

	C — High Expansion Foam System. D — Carbon Dioxide System. E — Approved Halogenated Extinguishing System. F — Other Automatic Extinguishing System. G — Hose Reel. H — Hydrant System.
Fire Alarm System	1. Automatic Fire Detectors System. 2. Manual Electrical Fire Alarm System. 3. Signal Indicator Alarm System. 4. Manual Alarm System.
Emergency Lighting	(a) Signal point units. (b) Central battery. (c) Generators.

Source: Law Ordinance, 2008

2.10 Issues Preventing Fire and Managing Fire in High-Rise Building

Inadequate fire prevention system such as fire detection, fire alarm and emergency lighting are one of the issues. Besides that, design and installation of fire prevention system installation and design are efficient and effective to prevent the fire from outbreaks (IEM, 2006). There is a limited practice of having Safety and Health Committee in a high-rise building and there is no proactive implementation toward fire prevention practices among building management and residents (Chien et al., 2013). Other than that public is lack of awareness of safety policies which include enforcement from building's management (Clegg Smith et al., 2007). Fire safety knowledge and occupant awareness need immediate attention to enhance fire prevention through adequate fire drill and fire evacuation activities (Akashah et al., 2017).

Other than that, Malaysia Fire Officer enforcement in inspection and design for building safety is not stringent enough. In other countries, Fire Engineer involvement is

able to enforce fire safety in building efficiency. Fire engineers are able to reduce fire, proper evacuation routes, reduce installation of fire equipment and also a reliable resource to prevent fire in the building. Fire in the building is increasing due to lack of expertise (Enright, 2014). Fire Safety in Design, Management and Use of Buildings - Code of practice is newly published and need to enhance its enforcement in order to prevent reoccurrence (Aziz et al., 2017).

Building management also not effectively spreads the awareness on fire prevention. Residents of the high-rise building are not well informed and educate on fire prevention (Tharmarajan, 2007). Abdul Wahab, (2015) research also find out that issues to prevent fire arise from building management. This is due to inadequate of building maintenance, managed funds, and maintenance efficiencies. The management system also not strict and management staff is not responsible. It shows there is no clear leadership in order to understand the development of fire safety in the buildings. Other than that, fire safety awareness is not developed among management staffs despite inspections and fire audit is conducted to access fire safety in the building (E & Zhou, 2016).

Malaysia is still lacking experience and guidelines are not standardized in managing high-rise residential buildings (Ta, 2009). Singapore and Hong Kong have enforced high-rise residential buildings earlier in 2009 provided with standard guidelines. Singapore and Hongkong have more population lives in high-rise residential buildings with low risk of fatality and should be a benchmark for Malaysia (Ali & Chen, 2018). A simple analysis and comparison with other country have been done by China to improve their fire safety problems (E & Zhou, 2016). Guidelines for building and equipment inspection are necessary in order to maintain and fulfil fire safety regulation. Besides that, guidelines are able to keep effectiveness on safety are updated (Chien et al., 2013).

2.11 Summary of Literature Review

Literature review is used to guide the researcher to develop proposed strategies and checklist for high-rise residential buildings. For this study, high-rise residential buildings are above 18 meters in height or roughly about 6 storeys. Hazard is identified and caused by fire over a period of time are considered in order to take preventive action. In this study, fire prevention is focused on high-rise residential fire since it has the high risk of fire outbreaks. Fire outbreak pattern from the residential area and hotel building is taken into consideration since both premises have similar casualties in event of a fire. It involves occupancy and fire safety plan to prevent fire. Based on research conducted, strategies to prevent fire is a positive solution for the premises and the focus is for high-rise residential buildings. Strategies to prevent fire outbreaks are a reviewed from a country such as Taipei, Hong Kong, Shanghai, Singapore, Dubai, Australia, Istanbul and others country which have already been developed on managing high-rise residential buildings. This strategy is useful to be implemented by adapting fire safety in Malaysia high-rise residential buildings.

High-rise residential building is mandatory to fulfil Law and Regulation of Malaysia such as Fire Services Act 1988, Uniform Building by Law 1984 and Sarawak Building Ordinance 1994. Despite with Law and Regulation, Malaysia Fire Safety is lack of enforcement and need to enhance in order to increase standards. These have caused several issues in managing and preventing fire such as inadequate fire safety equipment, lack of fire prevention awareness and less exposure to fire safety training and education. In this study, it is encouraged to develop strategies that involve residents and building management. This can be done by distributing a survey to an expert panel with knowledge and experience in the field of study. Expert's opinion is needed due to high risk of fire outbreaks and collected in order to develop proposed strategies and checklist for buildings management and resident's guidelines.

CHAPTER 3:METHODOLOGY

3.1 Research Methodology Process Flow

Methodology process in figure 3.1 is conducted to achieved research objectives. The process of methodology requires the researcher to perform survey and comprehensive analysis to set-up fire prevention standard. The research approach is collected by analysed expert's opinion and set-up standard based on other countries fire safety practices.

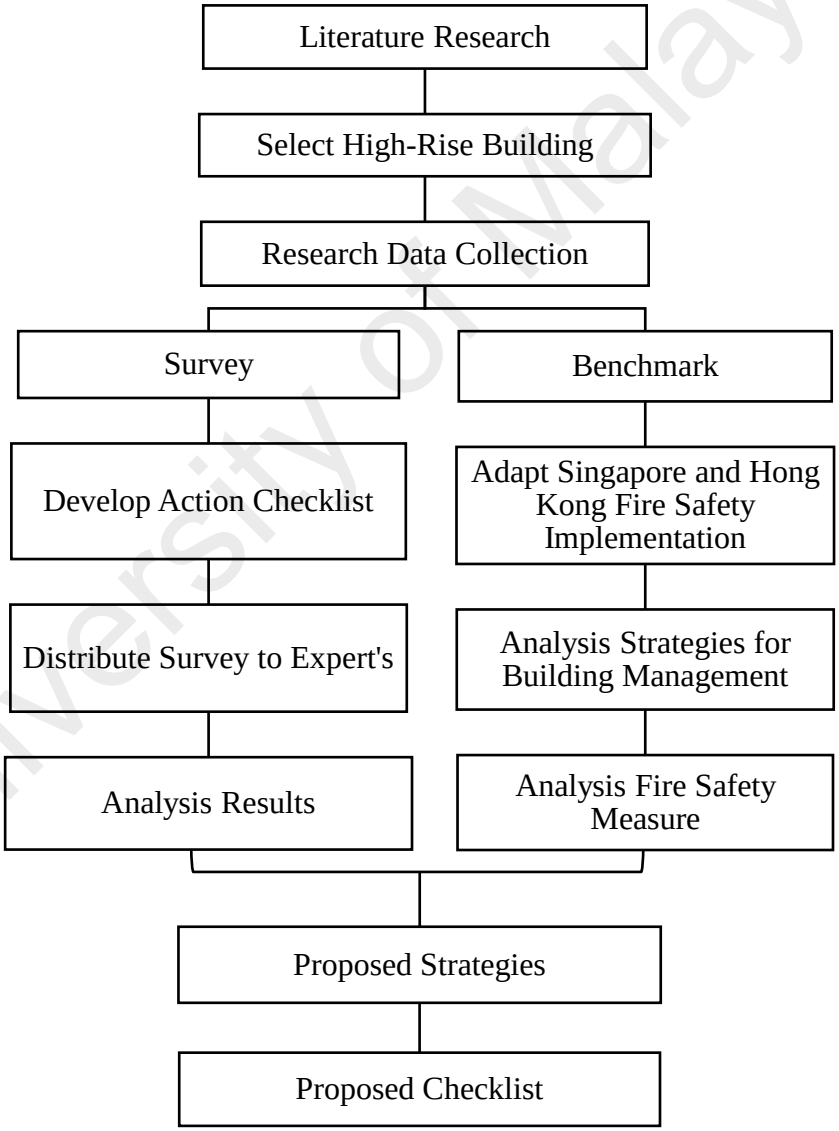

Figure 3.1: Methodology process flow

3.2 Select High-Rise Building

In this study, the focus is for high-rise residential buildings height of 18meter or roughly 6 storeys. The height is selected because firefighter appliances reach its limit access and require firefighting system in the building to operate. Besides that, high-rise building is a sleeping risk where residents are various in ages, health condition and transient presence in a strange building which causes them unable to identify the means of escape during emergencies. Proposed strategies and checklist to prevent the fire is suitable to reduce the risk of fires outbreaks.

3.3 Research Data Collection

Data collected is analysed and used to developed proposed strategies for building management in order to prevent the fire from outbreaks. There will be two proposed strategies developed which are based on survey results and benchmark from Singapore and Hong Kong fire safety implementation. Survey results are based on expert's response and each of the response is used as a support data in the discussion. Expert's response survey is shown as in figure 3.2. Strategies developed based on benchmark requires comprehensive reading and practical for implementation.

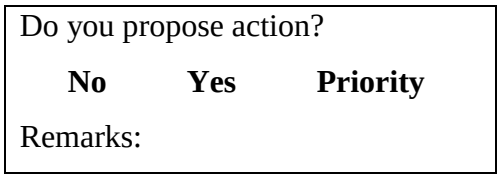

Figure 3.2: Expert's response options

3.3.1 Questionnaire Reliability

Reliability of the question is analysed by using Cronbach Alpha to verify the consistency of the questionnaire. It is an important test to evaluate then assessments on questionnaires. The results of Cronbach Alpha value must be above $\alpha = 0.70$ to ensure

that the questionnaire is reliable for discussion. Statistical Package for Social Science Version 20 (SPSS V20) software program is used to analyse the questionnaire reliability.

3.3.2 Expert's Selection

There are 20 expert panels that participate in this survey as recommended for best consolidation. The expert panel consists of an expert with knowledge and experience in this field of study. Field of study for this study is on fire prevention in high-rise residential buildings. Expert panels are selected based on their expertise in this field of study and based on their working experiences. For this study. there are two (2) Professors from Safety Health and Environment, six (6) Architect from Consultant, nine (9) Fire Officer from Fire Prevention Unit and three (3) safety practitioners from safety committee and safety and health officer.

3.3.3 Action Checklist Questionnaire

Action checklist is one of the methods in this study to develop a proper strategy based on expert's opinion. Action checklist is conducted to support the fire prevention strategies practices and instil fire prevention awareness in high-rise residential buildings. There will be three sections in proposed action checklist which minimises fire risks, the action for fire emergencies preparedness and action was taken for training preparedness. Each of the questions is an action required for building management and resident to prevent fire

Minimise the risk of fire is able to prevent fire. This is to ensure that the fire is not reoccurrence. This action checklist is a method to acknowledge residents and building management the danger of fire. Besides that, minimise risks are able to protect lives and properties. There are ten action checklists from this section and are listed below;

Q1.	Isolate flammable solids, liquids, and gases from sources of ignition such as open flames, heated surfaces or unprotected electrical wiring to prevent fires and explosions.
Q2.	Restricted storage of flammable materials such as the gas cylinder and only allowed to have one gas cylinder with proper ventilation in every resident's unit.
Q3.	When open flames are present such as welding, cutting or smelting, take adequate precautions such as isolating sources of fuel or combustible materials from the open flames. Any residual heat that is left in materials must be monitored until they have cooled and can no longer provide a source of ignition
Q4.	Clearly indicate ‘No-Smoking' sign in the building. The offense will be imposed with warning noticed or fine.
Q5.	Designate specific smoking areas or smoking zone with a clear sign and make sure the designated area free of flammable and combustible materials.
Q6.	Maintain all electrical circuits to assure adequate earthing to prevent spark, overloading, heat resistance and prevent short circuits. Use fixed wiring circuits instead of extension cords to avoid damage to internal wires and instead of multiple plugs to avoid the overloading of circuits.
Q7.	Residents are encouraged to installed self-contained smoke detector in their residence for early detection of fires and to give warning.
Q8.	Carbon monoxide detector and alarm are located at underground carpark and basement with regular inspection.
Q9.	Provide an adequate number of segregate waste bin to avoid accumulation of waste and scraps. Segregate waste such as paper, wood, plastics, fabrics or waste food.

Q10. Residents are encouraged to install home grilles that has escape features such as panels that can be unlocked and open. This is very useful for evacuation in case of emergencies.

Fire emergencies are part of fire prevention to ensure building management provided sufficient fire protection system in the facilities. This is to ensure the residents understand the process of evacuations provided with signage and firefighting equipment. There are twelve action checklists in this section that are able to prepare residents and building management for fire emergencies such as;

Q11. An evacuation plan and assembly point are clearly posted on every residence unit.

Q12. Clearly mark each exit route and provide emergency lighting so that exit routes are well lit during the day and night.

Q13. Provide an adequate number of exit stairways and means of egress at least two of adequate construction and support the rapid evacuation of all residents from floors above or below ground level.

Q14. Post a warning sign at each lift station on each floor indicating DO NOT USE THE LIFT FOR EVACUATION DURING A FIRE.

Q15. Keep exit routes clear from obstructing objects and assure that the exit route is continually unlocked and all doors in exit routes open in the direction of the flow of residents during an evacuation.

Q16. Provide fire detection equipment, such as smoke detectors and heat detectors in all residence levels. Make sure the alarm ring is loud enough to be heard by all residents during an emergency.

Q17.	Fire detection equipment shall be tested annually and approved by building management and Fire Officer.
Q18.	Place fire extinguishers in sufficient numbers at locations based on specific fire hazards. Always locate the fire extinguishers at the exit route and are easily seen from the area. Provide suitable fire extinguishers for the fire hazard.
Q19.	Mount fire extinguishers at a reasonable height and clearly mark each of their locations. Keep obstructions cleared from in front of each fire extinguisher.
Q20.	Carry out at least once a year fire drill and evacuation drill for all residents to alert existing and new residents of the building regarding the fire evacuation plan.
Q21.	Fire equipment should be inspected annually for proper maintenance by Fire and Rescue Department.
Q22.	Safety committee is made up of management staffs and residents. An annual meeting will be conducted and they have the authority to act on behalf of the other owners in the maintenance and management of common areas.

The third section is training preparedness which consists only two action checklists as listed below. Training preparedness is a method to educate and expose residents and building management to prevent fire. This is to ensure residents and building management are well informed and prepared for emergencies.

Q23.	Annually provide refresher training to safety committee team and emergency response team (ERT) on how to prevent fire hazards and the actions to be taken if a fire is detected, including emergency evacuation and basic firefighting procedures.

Q24. All residents are encouraged to participate in fire safety program to keep informed on building features, action should be taken during emergencies, practice correct action when emergencies and able to update new residents regarding fire safety program.

Action checklist is analysed based on 'No' and 'Yes' response. 'No' response is disagreement, while 'Yes' response is for agreement statement. This is analysed based on percentages of response. This structure is to make a clear agreement or disagreement on action checklist on fire prevention. The percentages of response are used as a supporting data in the discussion. Each action checklist will be discussed further in chapter 4 on the importance of each section to prevent fire. A graph is tabulated by section of action checklist versus percentages of expert's response. Action checklist questions will be represented by Q followed by its sequence numbering (n). For examples, Q1, Q2, Q3, until Qn.

3.3.4 Analysis Survey Strategies

Then, the action checklist practice is categorised as priorities implementation. All twenty-four-action checklist is ranked by experts. The aim of conducting the survey is to develop important aspect to prevent fire. A simple descriptive analysis based on expert's opinion is analysed by using Statistical Package for Social Science Version 20 (SPSS V20) software program. Open-ended questions in under 'Remarks' also part of implementation or mechanism suggestions. 'Remarks' from expert's is used to develop appropriate suggestions for better implementation. The survey is categorised by expert's opinion from compulsory implementation, good to implement and optional implementation. This category of priority to implement is ranked by percentages based on expert's opinion. The overall questionnaire priority is tabulated and the action checklist

will be summarised from the original questions for clear understanding. Further explanation of priorities categories will be discussed in chapter 4.

3.3.5 Analysis Benchmark Strategies

Benchmark is another method to developed strategies by comprehensive reading on Singapore and Hong Kong fire safety practice. Proposed strategies are developed based on Singapore and Hong Kong Code of Practice for Fire Safety. Developed strategies based on benchmark from both strong countries will able to give positive results to increase fire prevention standards. This would give a clear guide to methods used to reduce the risk of fire and indirectly enhance fire prevention strategy. It is easier to develop strategies based on other countries because the researcher is able to find issues that arise in managing and preventing fire, a solution to improve the issues, enhance the development of fire prevention and direct towards strong standards to prevent fire. By using this method, strategies for building management to manage the building and fire safety measure is developed. Both strategies will be tabulated in table and discussed further in chapter 4.

3.4 Development Checklist

A checklist is developed based on both strategies proposed. The checklist is developed based on the highlighted focus to prevent the fire by depending on survey and benchmark results. This checklist is developed to expose knowledge and to ensure that residents aware of building fire safety. Indirectly, fire prevention in the building practiced and to ensure that strategies to prevent the fire is practically implemented. Checklist expected highlight is such as;

(1) Electrical and appliances safety;

(2) Cooking safety;

(3) Escape plan;

(4) Exit routes;

(5) Exit sign and emergency lighting;

(6) Portable fire extinguisher;

(7) Automatic fire devices system;

(8) Lift;

(9) Parking and;

(10) House-keeping.

3.5 Safety Precaution

Fire prevention measures in high-rise residential should be high concerned on safety precaution of the building. This is because high-rise residential buildings are at high risk of fire outbreaks. Due to firefighter's limitation equipment, fire rescue above the sixth floor will be difficult and time-consuming. Based on a study conducted, fire equipment's and safety precautions signage in the building are fully complied with act and regulations. However, most of the residents are not aware of the importance of these facilities. The residents are not knowledgeable to ensure the fire protection system is functioning. The current high-rise residential building has less fire safety precaution due to;

i. No proper guidelines for residents and building management to prevention fire and keep the building safe;
ii. Less involvement of residents in building management fire prevention measures;
iii. No proper exposure to training on handling portable fire protection;

Besides installation of fire protection system, the involvement of residents and building management is needed. Therefore, the safety precaution in high-rise residential is conducted to develop practical strategies and guidelines for both parties. This is to ensure that fire prevention in the building is practical and sufficient.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Survey Validity and Reliability

Based on table 4.1, reliability test for this survey is analysed for 24 questions. Cronbach Alpha for the survey is $\alpha = 0.909$ whereas Arghami et al., (2016) research obtained value of $\alpha = 0.74$. This result shows that the survey is high reliability. High reliability is also obtained because of the structure of the questions which is based on fire prevention and most of the experts have the same opinion to improve fire prevention in high-rise residential buildings despite some disagreement. Therefore, a higher value of Cronbach alpha is able to develop reliable strategies and checklist for this survey. High effectiveness and confidence is achievable.

Table 4.1: Reliability statistics

Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
.909	.909	24

4.2 Current Fire Prevention Strategy

This strategy is developed as a guideline to prevent fire and to encourage fire prevention practice in the building. There is three concern practice to prevent fire which is minimising fire risks, fire emergencies preparedness and training preparedness in order to overcome current issues in high-rise residential buildings. This questionnaire is enhancing current fire prevention practice and expert's opinion is used to support this strategy.

Fire outbreak is preventable with proper practices by minimising the risk of fire outbreak. Minimising fire risk is one method in this study to solve or giving an option for

fire prevention implementation to reduce fire hazard. Examples of common fire hazard in residential building due to insufficient of fire protection system, no proper maintenance, no proper fire prevention plan, fire exits and egress is obstructed and lack of awareness in fire prevention. Residents should be aware of their residential building fire prevention condition. Home grille installation can be a fire hazard and it is advisable for residents to install escape features home grilled. This installation can minimise fire hazard and shorten the time for evacuation. Despite escape feature grille (Q10= 75%) shows low percentages of an agreement by the expert in figure 4.1, but this is one of the methods to minimise loss of lives of occupancy when fire outbreaks in the residence.

The most common fire outbreaks in residential buildings are from electrical appliances failure, smoking and cooking material. Electrical appliances and hot works such as renovation, welding, storage of gas cylinder and cooking should be isolated and performed adequate supervision. Electrical appliances should be visible and reachable. Isolation is one best method for smoking and cooking where it is separated from other room or building and this can reduce fire risks. Adequate supervision is by having a competent person with knowledge of fire prevention to supervise.

Besides that, smoking in the residential building should be prohibited and designated smoking area is provided in order to control the flammable substance in the building. This will enhance resident's practices towards good housekeeping. Waste segregation is also part of good housekeeping where waste is accumulated at a designated area. This designated area should be a distance from residents building to control and minimise flammable substance in the building. In Malaysia, most of the residents have the knowledge to prevent fire but unable to practice it properly.

A study has shown that Malaysian households is not equipped with firefighting equipment at home by giving a reason that they never thought of having it. Dubai has implemented a mandatory fire equipment in each high-rise resident to prevent fire. This

also implemented in China and Malaysia should start to practice this fire prevention safety by installing fire protection system at home. The survey results in figure 4.1 have shown an agreement on Q7=95% which encourage residents to install self-contained smoke detector in their residence. The smoke detector should be installed in the living room and bedroom in order to reduce sleeping risk. It is the cheapest and effective way to prevent fires. Fire protection system is important for high-rise residential building. All areas of the building including underground carpark and basement should be provided with fire protection systems such as carbon monoxide detector and alarm. Based on figure 4.1, install carbon monoxide at underground carpark and basement has the least preferable action and recommends for sprinkler installation.

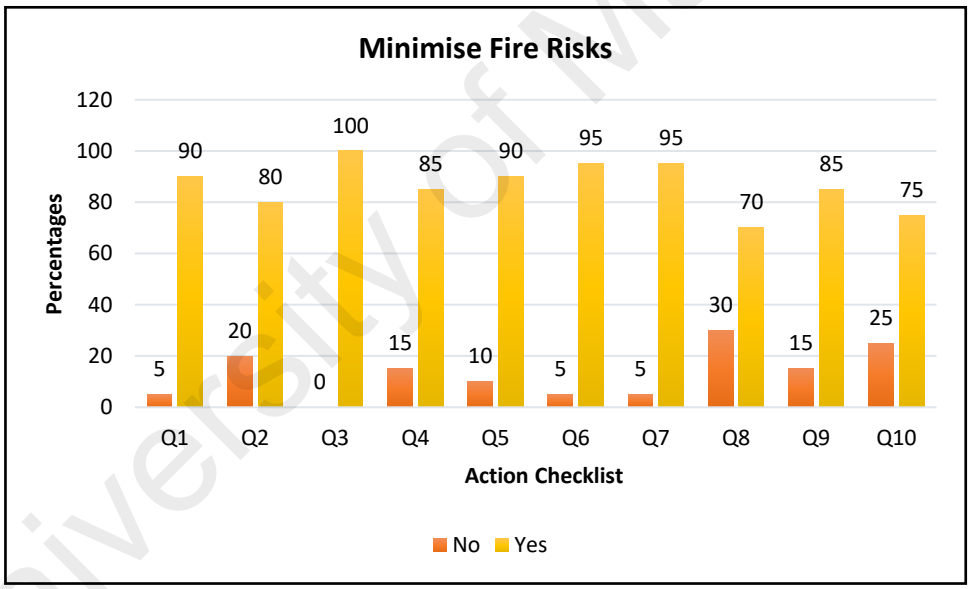

Figure 4.1: Percentage of expert's response to minimise fire risks

Fire emergencies preparedness is important to fire warning to residents and building management to able to provide sufficient fire protection system within the building. Fire emergencies action checklist is one of the general strategies to prevent fire. It consists of fire management team, fire emergency procedures, and fire installation maintenance. Survey results in figure 4.2 shows that experts also agree that this method is able to prevent fire in high-rise residential. There are several strategies that are able to achieve

fire emergencies preparedness which requires commitment from building management and residents such as comply with act and regulation, develop involvement in building management with residents and enforcement procedures.

Fire emergencies are to ensure that building management always complies with fire act and regulations. This action is compulsory for building management to provide sufficient amount of fire protection system and make sure it is in good condition at all time especially during emergencies. Fire protective that requires the high-rise building is active and passive fire protection system. According to act and regulation in Malaysia, high-rise building above 18meters are required to install fire protection system. This is because of a high risk of fire and sleeping risk involved. Installation of fire protection needs to comply with code and standard of fire protection system. This is to ensure it is sufficiently working.

By developed safety committee team in high-rise residential buildings, the committee is able to have more responsibilities to make sure the buildings are in the safe condition. It is necessary for safety committee team to get involve with authorities such as fire officer, police and district office regarding the condition of the buildings. This will show commitment and effective methods towards managing fire prevention in high-rise residential building. Refer to figure 4.2, Q22=95% received positive agreement by expert's where safety committee has the authority to maintain manage the building on behalf of the owner. Safety committee also able to educate residents to prevent fire and react in case of fire outbreaks. Therefore, safety committee is required to have the least knowledge in fire prevention and keep on update information regarding high-rise residential issues need to be documented for future practices.

Other than that, it is important that fire emergency procedures are recorded and documented. Fire emergencies procedures needed are such as evacuation plan, exit route with lighting, and an adequate number of exit routes and egress. This procedure is to

ensure crown is controlled during emergencies. Besides that, fire and evacuation drill at least once in a year is to guide and prepared residents and safety committee. This procedure is a good practice to reduce fatalities as implemented in China. Stringent enforcement by building management is crucial to make sure this action effective.

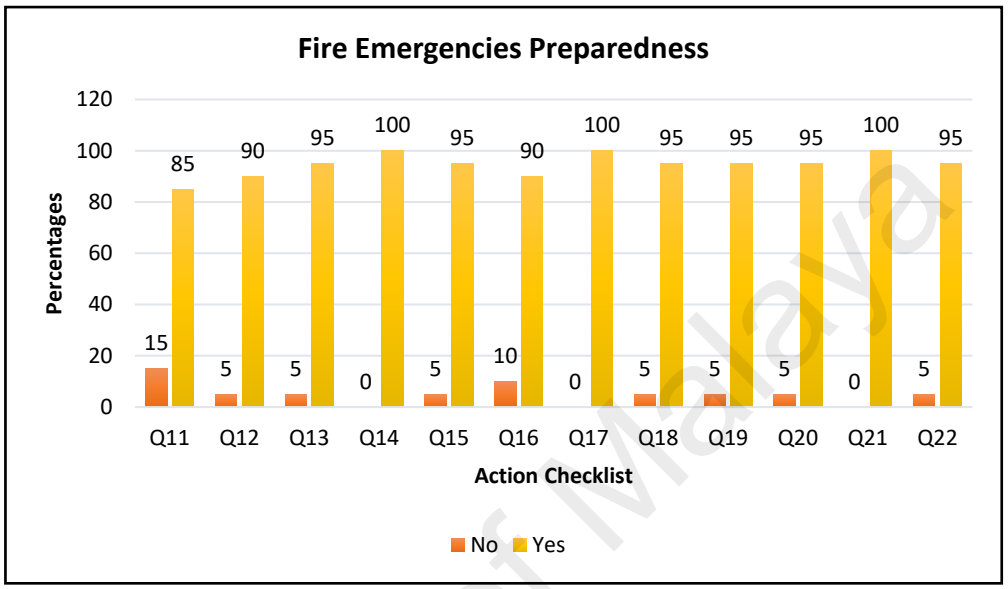

Figure 4.2: Percentages of expert's response on fire emergencies preparedness

Training preparedness is one of the methods to keep residents aware of their surrounding regarding fire prevention. Building management safety committee shall conduct refresher training. This is to show commitment to prevent fire in the buildings and updated on current issues in high-rise residential buildings. Expose to a danger of fire outbreaks and familiar with methods to handle fire outbreaks are able to change behaviour of residents towards fire preventions in high-rise residential buildings. It is important to educate residents on the risk and methods to prevent fire. Figure 4.3 shows that experts also agree that training preparedness is needed for both parties. This is because training preparedness is one of the basic methods to educate residents. Indirectly, sleeping risk in the building also reduces by this fire prevention expose. The residents are encouraged to participate in fire safety program from a various range of ages and this program is encouraged to be conducted in the residential buildings in order to encourage all residents

to participate. Safety program such as a workshop on manual handling fire extinguisher, familiar with the building structure, safe evacuation methods and effective methods prevent the fire from spreading by using house material is useful for building management and residents. This will ensure that the high-rise residents are well informed and educated.

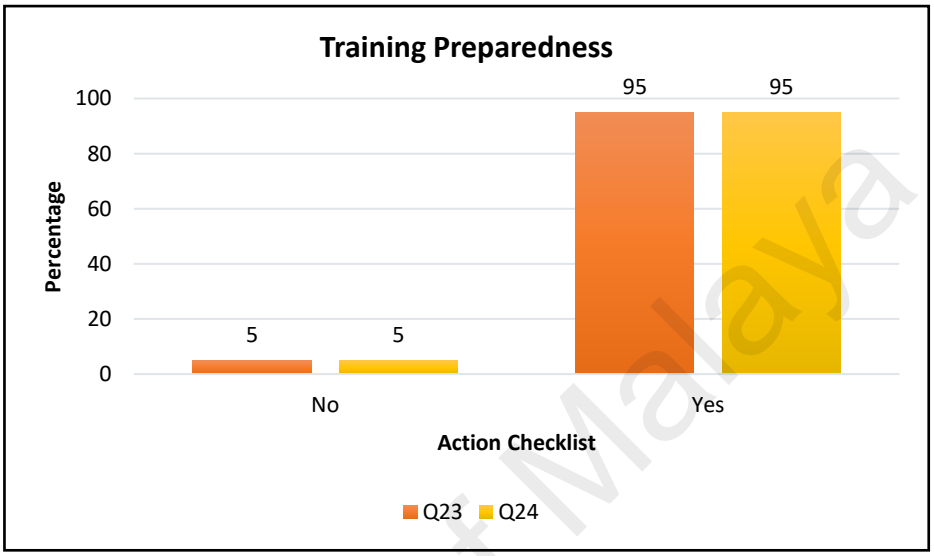

Figure 4.3: Percentages of expert's response on training preparedness

4.3 Priorities Fire Prevention Strategy

Priorities strategies are used to categories fire prevention implementation. It is practical to have proper strategies that consider most of fire safety aspects focusing on preventing fire in high-rise residential buildings. Figure 4.4 shows the overall percentages of priorities based on expert's opinion and table 4.2 is the overall priority implementation listed from high priority to low priority. List of priority is categorised based on expert's opinion. High and compulsory priority is selected between frequencies of 55% until 40%. Medium priority and good to implement is between percentages of 35% to 20% while low and optional priority is between of 15% and lower percentages.

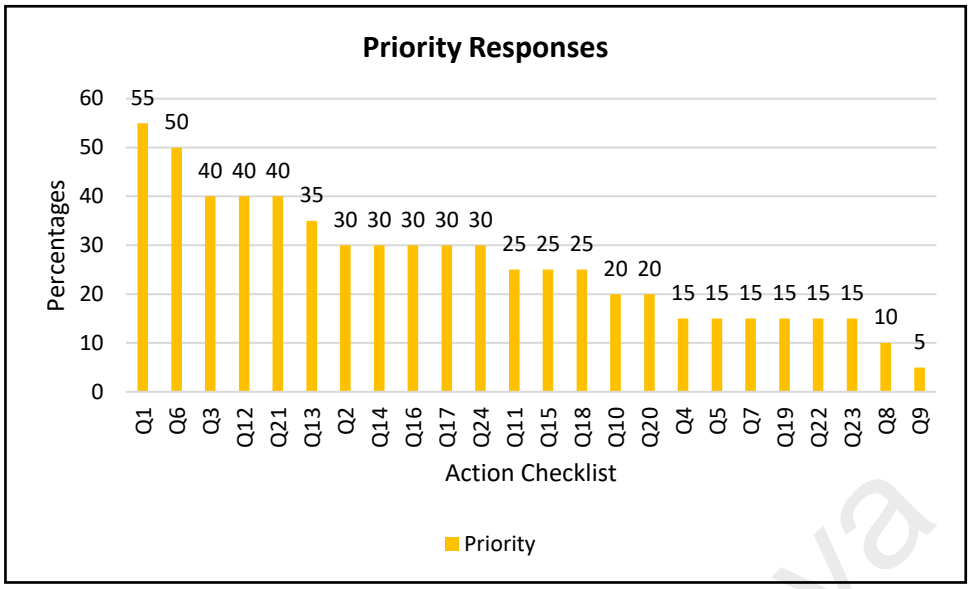

Figure 4.4: Percentage of expert's response on priority action checklist

Proposed strategies are developed in order to have clear guidelines to prevent fires in high-rise residential buildings. This is because fire outbreaks in high-rise buildings are high risk and if not managed properly, it may cause casualties. Causes of fires and the target area are identified in order develop effective strategies. Based on literature review, fire cases normally caused by faulty or overloaded electrical appliances, smoking material and through cooking equipment. Despite the building is fulfilled by fire certificates from Fire and Rescue Department, the building is not safe enough without installation of proper fire equipment. Building management and residents also lack awareness and implementation of methods to provide a safe building. Proper strategies are efficient enough to prevent fires together with the commitment from building management and residents. Proper strategies are covered action such as reduce fire ignition, remove the opportunity of fire outbreaks, increase exposure and knowledge on fire prevention practices and involves authorities in implementing strategies

Table 4.2: Overall questionnaires priority

No	Strategies	Overall Priority
1	Isolate flammable sources.	High Compulsory
2	Maintain all electrical circuits.	
3	Adequate supervision on any open flames activities.	
4	Clearly mark each exit route and provide emergency lighting.	
5	Fire equipment inspected annually.	
6	Adequate number of exit stairways and means of egress	
7	One gas cylinder in every resident's units.	Medium Good to implement
8	Posted warning sign at each lift lobby.	
9	Provide fire detection equipment.	
10	Tested fire detection equipment.	
11	Residents are encouraged to participate in fire safety program	
12	Evacuation plan and assembly point is clearly posted.	
13	Keep exit routes clear from obstruction.	
14	Place sufficient number of fire extinguishers	
15	Installed escape features home grille.	
16	Once a year fire drill and evacuation drill.	
17	'No - smoking' sign.	Low Optional action
18	Designated smoking area.	
19	Installed self-contained smoke detector in resident's units.	
20	Mount fire extinguishers at a reasonable height and clearly mark.	
21	Create safety committee organisation in the buildings	
22	Annual refresher training for safety committee	
23	Installed carbon monoxide detector and alarm at underground carpark and basement	
24	Implementing good housekeeping practices.	

4.3.1 High Priority – Compulsory Action

High priority is defined as compulsory to implement and there is six action checklist that are categorised at high priority based on expert's panel opinion which the major implementation is to isolate flammable sources and maintain all electrical circuits. This is a good strategy to minimise fire risk that occurs in high-rise residential as there are many cases of reported in residential related to flammable source and electrical faulty. In order to enforce compulsory implementation, building management needs to perform a regular inspection of flammable sources, electrical voltage, and fire equipment. Building facilities such as clearly mark each exit route provided with emergency lighting and an adequate number of exit stairways and means of egress also compulsory to implement. This action also to make sure building is safe and compliance with act and regulations.

4.3.2 Medium Priority – Good to Implement Action

Medium priority category is defined as good to be implemented. There are ten action checklists that fall under this category. Mostly action checklist that falls under medium priority is the commitment by residents and building management. This action checklist is to make sure building management is taking full responsibilities of fire-fighting equipment, fire certificates and fire hazard in the buildings. By performing action checklist, residents are well informed of management activities such as inspection, maintenance and confident that the building is in safe conditions. Besides that, commitment requires resident's and building management cooperation such as participate in fire safety program, proper handling gas cylinder, installed approved house grille and participate in fire and evacuation drill. Residents also should be responsible to make sure exit routes free from obstructions.

4.3.3 Low Priority – Optional Implementation

Low priority is an optional implementation for fire prevention strategies. Any practical implementation that suitable for high-rise residential buildings is allowable. There are eight action checklists that fall under optional implementation. Based on expert's opinion, some of the action checklists are not suitable or difficult to be implement for entire high-rise residential buildings. For example, most of the expert give their opinion that 'No-smoking' signage and design smoking area is not suitable and difficult to be implement for high-rise residential buildings. Despite that, research strongly encourages to implement in the buildings as this action can prevent fire. Based on research conducted in Sweden and China, 'No-smoking' signage has effectively reduced fire outbreaks (Runefors et al., 2017; Xin & Huang, 2013). Therefore, researcher and few experts have suggested to post 'No-smoking' signage at every entrance of the buildings and designated smoking area at an open area. This action is able to control flammable substance from smoking residents or visitors. Table 4.3 lists suggestion by experts and for comprehensive reading in order to achieved best implementation.

Table 4.3: Suggestion to implement low priority

Action checklist questions	**Suggestion to implement**
'No - smoking' sign.	Posted at every entrance of the buildings
Designated smoking area.	Design at open area within the building
Installed self-contained smoke detector in resident's units.	Installed at living room and bedrooms or provided with fire blanket.
Mount fire extinguishers at a reasonable height and clearly mark.	Place the fire extinguisher on designated area for easy handling
Safety committee is made up from management staffs and residents.	Each floor has their representatives and involves local authorities
Annual refresher training for safety committee	Training conducted in the buildings to make sure residents are able to participate

Installed carbon monoxide detector and alarm at underground carpark and basement	Installed sprinkler or provide proper ventilation
Implementing good housekeeping practices.	Frequent waste collector and design outside the buildings.

4.4 Benchmark Fire Prevention Strategy

Benchmark is created based on Singapore and Hong Kong fire safety practices. This is because both countries have successfully lowered the risk of fire outbreaks in high-rise residential building despite both have the most population in high-rise residential. This proposed strategy is mainly for building management in order to ensure the building is free from fire outbreaks. Competence person is hired and required to revise and update report to the relevant authority and keep it documented for building management. Strategies adapted from Singapore and Hong Kong are being developed to guide building management to manage the buildings accordingly as described in table 4.4. Therefore, this strategy can be a benchmark since Malaysia is still at the beginning stage to implement fire prevention. The proper action is able to improve fire prevention standard. This strategy is a good practice to introduce fire prevention to building management and residents.

Table 4.4: Strategies for building management

i.	Control fire hazard in the buildings.
ii.	Develop safety committee to take responsible.
iii.	Expose building management and resident with safety program conducted by fire and rescue department.
iv.	Practices fire drill and fire evacuation twice a year.
v.	Monitor maintenance and hot work activities in the buildings.
vi.	Perform scheduled inspection regularly.
vii.	Investigate and replace faulty equipment’s.

viii.	Develop fire prevention checklist to residents.
ix.	Implement fire prevention standard in the buildings.

Another strategy to prevent the fire is by implementing fire safety system. This is one of the best strategies to implement in high-rise residential buildings. Fire safety is mandatory to be implemented in high-rise residential buildings as stated in act and regulation. Despite just stated in act and regulation, it is better to list the importance of fire safety for building management so that it is a standard strategy which is easier to understand and comply as shown in table 4.4. Other than that fire safety system is also tabulated in table 4.5 for is passive and active fire safety system. This is to ensure no fire prevention measure will be missing.

Table 4.5: Fire safety measure implementation

Fire Safety System	**Malaysia**
Passive Fire Protection	
Means of escape	x
Means of Access	x
Fire resistance construction	x
Active Fire Protection	
Audio/visual advisory system	
Automatic actuating devices	x
Emergency generator	
Emergency lighting	x
Exit sign	x
Manual fire alarm system	x
Wet and dry riser /hose reel system	x
Fireman's lift	x
Fire-fighting and protector staircase	x
Fire control alarm panel	x
Fire detection system	x
Portable hand operated appliances	x

Pressurization and ventilation system	x
Sprinkler system	x
Static or dynamic smoke extraction system	

4.5 Proposed Checklist for High-Rise Residential

The checklist is used for high-rise residential buildings residents as a guide and methods to be more aware of fire prevention in the building since building management are mandatory to comply with Fire Services Act and Regulation. Indirectly, this will able to help building management to improve fire safety in the building in order to prevent fire. The checklist is developed to ensure that proposed strategies are implemented well and both parties such as building management and resident committed to make the building free from fire outbreaks. However, the checklist is not possible to cover all aspect but as a guideline to manage and prevent fire in high-rise residential buildings. The checklist is developed for residents as a general preparation to meet proposed strategies for building management.

It is also a method to notify and educate residents regarding the most important action in high-rise residential buildings. Refer to Appendix C for the proposed checklist. Residents are able to use this checklist to make sure the residential buildings are in safe condition practically to preventing fire. Any missing action should be informed to building management or safety committee. Local authorities should be informed of any doubt regarding action checklist. Involvement of local authorities is important to give information regarding building condition. Building management should take action on any 'No' responses from the residents regarding items on the checklist. Not practical implementation is feasible to change based on suitability as far as practicable towards the strategy to prevent fire. There are ten (10) checklist items listed such as electrical and appliances safety, cooking safety, escape plan, exit routes, exit sign and emergency

lighting, portable fire extinguisher, automatic fire equipment system, lift, parking and housekeeping. These checklists are used to educate resident on the importance to keep the building safe from fire.

4.5.1 Electrical and Appliances Safety

Since electrical is one of major causes of fire outbreaks, precaution such as investigation is able to prevent fire. The investigation should be done to make sure there is no problem and electrical usage is not overloaded. This is to make sure there is no short circuit and overloaded electrical usage. Other than that, building management should supervise any renovation or welding and only allow competence contractor to perform the activities. Residents should practice electrical and appliances safety by practicing;

(1) All electrical appliances are approved by SIRIM;
(2) All electrical cords are in good condition and not broken;
(3) All plug outlets are safe and do not feel warm (If it's warm, call management for inspection);
(4) Any renovation is supervised;

4.5.2 Cooking Safety

Cooking needs open flames and this activity is dangerous and should take precaution while handling. Cooking activities should be monitored by adults and make sure there is enough ventilation or cooking hood is used to circulate the air in the area. This is to make sure there is no presence of gas leaked while cooking which can contribute to fire. In order to make sure cooking safety is achieved, residents need to make sure each of cooking approach in table 4.6 is implemented.

Table 4.6: Cooking safety approach

Area of Concern	Action taken
1. Open flames	To be monitored regularly by adults
2. Cooking area	To ensure the area is always free from flammable materials
3. Number of Gas Cylinder (GC)	Best Available Technique (BAT) • 1 GC per house. • 2 or more GC needed, proper ventilation should be implemented.
4. Storage Area for GC	Far from: 1) Flammable substances 2) Heating material with proper ventilation system

4.5.3 Escape Plan

Escape plan might not be part of fire prevention but this plan is necessary for residents to evacuate from the building during emergencies. Residents should be well informed regarding escape route in case the nearest route is obstructed by smoke or caught in the fire. It is advisable for safety committee to make up from building management and residents to have a smooth evacuation and proper action take place. The escape plan should be practiced in the building by;

(1) Fire escape plan is printed and placed in the resident's unit;

(2) Everyone is informed where is assembly point;

(3) Participate in fire drills and fire evacuation;

(4) Every resident knows the emergency number;

4.5.4 Exit Routes

Adequate exit routes are important in every building. This is because to occupy large number of residents might seem impossible but with proper exit routes and plan, this strategy is possible. The fire door is installed and wide enough to allow enough number of residents to pass through in event of emergencies and well fitted. Exit routes should have;

(1) All exits route is free from obstacles;

(2) Fire door installed at escape routes;

(3) 'Keep Close' signage at fire door;

(4) Swing of the door in direction of escape;

(5) Fire doors are closed fitting;

(6) Fire doors unlocked during operating hours;

4.5.5 Exit Sign and Emergency Lighting

Signages and lightings is important to notify residents routes of exits. This is an effective guide to lead residents to evacuate from the building in case of fire outbreaks. Directional exits are necessary to lead residents to evacuate. Exit signages should have comply with the colour code of green and white combination. This is a standard for exit signages and unfamiliar residents or visitors will easy to lead towards exit routes. Emergency lighting and exit signage should come together. If the power supply fails during an emergency, emergency lighting is able to lit during day and night. The illuminations should be able to lighten the area of exit routes. Residents need to make sure the building is;

(1) 'EXIT' sign provided along staircases and escape routes;

(2) Visible exit signage;

(3) Directional exit sign provided where necessary;

(4) Exit sign complied colour code of green and white combination;

(5) Emergency lighting provided along staircases and escape routes;

4.5.6 Portable Fire Extinguisher

The portable fire extinguisher is a very useful fire equipment to fight the fire. It is a good practice to have this equipment at each resident house but it depends on the household whether to have or not. This is because each building is mandatory to provide portable fire extinguisher and residents are encouraged to use as the first defence. The suitable portable fire extinguisher should be selected in the building such as Carbon dioxide (CO_2) and ABC powder. In the presence of portable fire extinguisher, building management should perform a physical inspection on the condition and properly maintain by a licensed contractor. Based on Fire Services Law, the portable fire extinguisher should be mounted 1-meter height from the ground or provide space on the ground for easy handling. The resident should ensure that this portable fire extinguisher is;

(1) Properly hung or placed;

(2) Clear from obstruction;

(3) Serviced by licensed contractor half-yearly;

(4) Services scheduled is provided;

(5) Provide with instruction on handling;

4.5.7 Automatic Fire Devices System

High-rise residential buildings really need the presence of automatic fire devices system compares to other building due to sleeping risk in the buildings. It is important to know that fire and smoke alarm are sufficiently covered most of the building areas. The alarm should be in general sounding which able to notify residents in any cases of emergencies. Residents should be able to interpret the message and take action

accordingly. Therefore, safety program is necessary to ensure residents are well informed and able to take action in case of fire emergencies. Therefore, the best practice is;

(1) Fire and smoke alarm is at sufficient coverage;

(2) Sprinkler is installed at every level;

(3) Detector point is not obstructed/painted;

(4) General sounding throughout the building;

(5) Fire alarm is frequently tested;

4.5.8 Lift

Lift is one of access to high-rise residential building and one of major commuting in the building. Besides that, high-rise building is defined as the building where residents are dependable on an elevator to reach their floor. During emergencies, residents are not allowed to commute using the lift for safety purposed. Therefore, warning notices such as '*Do Not Use the Lift for Evacuation During Fire'* should be a place at lift lobby and being noticed by residents. Therefore, the resident should be aware that;

(1) Warning notice for fire situation provided;

(2) Storey numbering for lift lobbies provided;

(3) Lift Services scheduled is provided;

4.5.9 Parking

Even though parking is the least preferable priorities in the proposed strategies but precautions should be taken. Besides that, parking area for high-rise residential usually place at lower ground of the building and if fire outbreaks, it will spread faster and casualties may happen. Proper ventilation is appropriate to reduce heat from idle vehicles and sprinkler are the first responder toward emergency in the area. This action is able to

reduce the probability of fire outbreaks from the parking area and residents need to make sure that parking safety is achievable. Table 4.7 shows different implementation for a different parking area.

Table 4.7: Parking safety

Area of concern	Best Available Technique (BAT)
1. Underground car park 2. Basement car park	• Proper ventilation • Installed Sprinkler
3. Open area car park	• Proper Ventilation

4.5.10 Housekeeping

Proper housekeeping is needed to make sure the buildings are organised and free from rodents. The building should be clear from smell and residents should be aware that waste can be hazardous when caught in the fire. Besides, segregate of waste accordingly such as paper, plastics, aluminium, and others are good practices. Other than that, designated place for waste should be outside of the building instead of in the building to reduce the amount of substances that are able to caught on fire. 'No-smoking' signage should be placed at each entrance of the building to notify residents and visitors. This is to control flammable substances in the building. As options, the designated smoking area is suitable for residents to minimise flammable substance in the building. Therefore, the resident should be notified that;

(1) Waste collection is collected at least 3 times a week;

(2) Waste is not accumulated;

(3) 'No-Smoking' signage at every entrance of the buildings;

(4) Smoking is only allowed in designated area;

4.6 Overall Summary

Based on results and survey analysis, fire outbreaks in high-rise residential buildings can be prevented through involvement and commitment from building management and residents. Strategies are developed based on Expert's opinion and benchmark. These proposed strategies are developed to build knowledge to building management and residents on the action that should be taken to prevent fire. Prioritise actions are able to guide building management and residents on actions that should be taken from compulsory implementation, good to implement and optional implementation. Besides that, benchmark implementation based on Singapore and Hong Kong fire safety implementation is for building management to develop strategies to manage and develop fire protection system checklist to make it easier to understand. Therefore, checklist is developed for residents to make sure the strategies are practically implemented. Involvement of residents is able to make sure that residents are aware of their building fire safety. The researcher hopes that these strategies and checklist are effective and efficient to prevent fire in high-rise residential buildings.

CHAPTER 5:CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Strategies to prevent fire in high-rise residential buildings come into concern when researcher realised that there are many issues regarding managing the building and no proper strategies to prevent fire despite compliance with Law. Besides that, there are no comprehensive guidelines on strategies implemented. These strategies are implemented to reduce common causes of fire outbreaks and able to instil safety awareness among high-rise residential building management and residents. Fire outbreaks in high-rise residential building are high risk due to its height, difficulties for evacuation and fire spread faster in vertical buildings. Therefore, objectives of this study are achievable by conducting;

1. Expert' opinion is analysed and used as a supporting detail in current fire prevention strategies. This strategy is used to develop fire prevent highlights such as (i) improvement of fire protection system in high-rise buildings, (ii) develop safety committee involving local authorities, (iii) effective emergency plan, (iv) compliance with act and regulations and (v) enforcement by building management to prevent fire. The outcomes of these strategies are based on survey questions which consist of three section such as (i) minimise fire risks, (ii) fire emergencies preparedness and (iii) training preparedness.

2. There are two proposed strategies developed through this research which are proposed strategies based on survey and benchmark. Expert's consolidation is one of the methods to achieve confidence and effectiveness of fire prevention. Strategies proposed by the survey are developed based on priorities from expert's opinion analysis. Overall priorities based on expert's opinion are categorised as high priority, medium priority, and low priority. While practices implemented

from Singapore and Hong Kong fire safety are method to create a benchmark and able to improve the standard. This proposed strategy is to ensure fire prevention issues is able to be solve and enhance the standard of fire prevention.

3. The checklist is developed to educate and expose resident regarding fire prevention safety condition in the building in particular to prevent fire. The checklist is developed to involve both parties to prevent fire and at the same time give warning on building conditions. Any negative feedbacks or suggestions from residents should be investigated and performed maintenance. Proper implementation of strategies is able to ensure fire in high-rise buildings is preventable.

Therefore, the objectives of this research are achievable by developing proposed strategies based on expert's opinion and proposed strategies based on Singapore and Hong Kong implementation for building management while checklist is developed for residents to ensure the strategies are practical and implemented well. By developing both strategies and checklist, the researcher believes that fire in high-rise residential building is preventable.

5.2 Recommendation for Future Work

In this study, the strategy is proposed to ensure building management understand and easy to comply with act and regulation to prevent fire. Recommendation for future work is to ensure this propose strategies and checklist is practically implemented in high-rise residential buildings throughout Malaysia. In order to achieve this, the future recommendations are to:

1. Distribute the proposed strategies and checklist to residents and building management of high-rise residential buildings. This is to observe feedbacks from

residents and building management on the implementation. Feedback is used to ensure whether the proposed methods are practical or suitable for practiced. Any suggestion for further improvement are recommended and documented. The proposed strategies should be revised and kept updated for better implementation.

2. Expert's opinion should be revised at least 3 times in order to make sure the suggestions proposed are relevant due to high risk of fire outbreaks in high-rise residential buildings. The revision is based on resident's and building management feedback to ensure the practicability of implementation. This is to ensure new information, issues and suggestions should be taken into considerations.
3. Besides that, face to face survey should be conducted. This is to make sure the objectives on action checklist are understood by the experts. Other than that, the researcher is able to communicate and explain the survey questions well. Some of the questions might confuse expert's in giving their opinion and a clear response.
4. To enhance implementation of fire prevention, governance, society, and stockholder should give incentives such as funding for fire protection equipment and proper fire safety design to encourage residents and building owner to implement the fire prevention strategies. This is to make sure fire prevention strategies in high-rise residential building are taken seriously and continuously improved.

REFERENCES

Abd-Wahab, S., Sairi, A., Che-Ani, A. I., Tawil, N. M., & Johar, S. (2015). Building maintenance issues: A malaysian scenario for high-rise residential buildings. *International Journal of Applied Engineering Research,, 10(6)*(15759-15776.).

Ahrens, M. (2016). *High-Rise Building Fires*. Retrieved from https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics/Occupancies/oshighrise.pdf

Akashah;, F. W., Baaki;, T. K., & Lee, S. P. (2017). Fire Risk Assessment of Low Cost High Rise Residential Buildings in Kuala Lumpur: A Case Study.

Ali, H. B., & Chen, I. T. (2018). *Paper 6 - Passive & Active Fire Strategies.* Paper presented at the International Conference and Exhibition Malaysia Sunway Resort Hotel, Kuala Lumpur

Alqassim, M. A., & Daeid, N. N. (2014). Fires and related incidents in Dubai, United Arab Emirates (2006–2013). *Case Studies in Fire Safety, 2*, 28-36.

Arghami, S., Kamali, K., & Mahboubi, M. (2016). Development of a Fire Safety Checklist for Dormitories. *Journal of Human, Environment, and Health Promotion, 2*(1), 20-31.

Aziz, A., Teng, C. S., & Giang, T. H. (2017). MS1183 Fire Safety Code of Practice Series II – Means of Escape Design. In T. I. o. F. E. U. M. Branch (Ed.), *Fire Safety Seminar and Workshop*.

Bakar, D. H. B. A. (2006). *Guide To Fire Protection In Malaysia* (2nd ed.).

Baker, J., Bouchlaghem, D., & Emmitt, S. (2013). Categorisation of fire safety management: Results of a Delphi Panel. *Fire Safety Journal, 59*, 37-46.

Butterworth, N. (2013). *Fire Strategies for Super-high Rise*. Retrieved from https://www.bre.co.uk/filelibrary/Sustainability20through%20Planning/Fire_strategies_for_tall_buildings_Neal_Butterworth.pdf.

Campbell, R. (2017). Structure Fires in Dormitories, Fraternities, Sororities and Barracks. *National Fire Protection Association*.

Chien, S. W., Chen, Y. Y., Lin, C. Y., Shen, T. S., & Huang, P. T. (2013). Upgrading Fire Safety Strategies for the Existing Non-residential Occupancies in Taipei City. *Procedia Engineering, 62*, 1096-1103.

Chien, S. W., & Wu, G. Y. (2008). The strategies of fire prevention on residential fire in Taipei. *Fire Safety Journal, 43*(1), 71-76.

Chow, W.-k., Fong, N.-k., Liu, C.-h., Tam, T.-k., & Yue, T.-k. (2013). Fire Safety Strategies for Supertall Buildings in Hong Kong.

Clegg Smith, K., Cho, J., Gielen, A., & Vernick, J. S. (2007). Newspaper coverage of residential fires: an opportunity for prevention communication. *Inj Prev, 13*(2), 110-114.

Craighead, G. (2009). *High-Rise Building Definition, Development, and Use* (3rd ed.): Elsevier Inc.

E, Y.-t., & Zhou, L. (2016). The Research on the Current Safety Status of High-rise Building at Home and Abroad. *Procedia Engineering, 135*, 574-577.

Enright, P. A. (2014). Work Health & Safety legislation; the fire engineer's neglected duty? *Case Studies in Fire Safety, 2*, 1-8.

Haitao, C., Leilei, L., & Jiuzi, Q. (2012). Accident Cause Analysis and Evacuation Countermeasures on the High-Rise Building Fires. *Procedia Engineering, 43*, 23-27.

Hariz Mohd, & Ying, T. P. (2017). Keramat tahfiz tragedy: Seven arrested, police say case solved. *New Straits Times*. Retrieved from https://www.nst.com.my/news/nation/2017/09/280556/updated-keramat-tahfiz-tragedy-seven-arrested-police-say-case-solved

Hu, Y.-n. (2016). Research on the Application of Fault Tree Analysis for Building Fire Safety of Hotels. *Procedia Engineering, 135*, 524-530.

IEM. (2006). *Safety Against Fire In Buildings.* The Institution Of Engineers, Malaysia

Kamaruzzaman, S. N. B., Tan, Y. R., Akashah, F. W., Mahyuddin, N., Ali, A. S. B., Azmi, N. F. B., & Chua, S. J. L. (2016). The analysis of fire losses and characteristics of residential fires based on investigation data in Selangor, 2012-2014. *MATEC Web of Conferences, 66*, 00109.

Laws Ordinance, S. (2008). *Chapter 8: Building Ordinance*.

Liu, X., Zhang, H., & Zhu, Q. (2012). Factor Analysis of High-Rise Building Fires Reasons and Fire Protection Measures. *Procedia Engineering, 45*, 643-648.

Ma, Q., & Guo, W. (2012). Discussion on the Fire Safety Design of a High-Rise Building. *Procedia Engineering, 45*, 685-689.

Nation. (2017). Vital for homes to have smoke detector and extinguishers. *The Star* Retrieved from https://www.thestar.com.my/news/nation/2017/02/07/vital-for-homes-to-have-smoke-detector-and-extinguishers/

Othuman Mydin, M. A., Ismail, I., & Taib, M. (2014). Appraisal of Passive and Active Fire Protection Systems in Student's Accommodation. *MATEC Web of Conferences, 10*, 06002.

Oven, V. A., & Cakici, N. (2009). Modelling the evacuation of a high-rise office building in Istanbul. *Fire Safety Journal, 44*(1), 1-15.

Rashid, M. N., Sulaiman, A., & Mahyuddin, M. (2012). Exploring Fire Safety Awareness Among The Malaysian Public.

Richardson, K. (2013). Fire Safety in High Rise Apartment Buildings.

Runefors, M., Johansson, N., & van Hees, P. (2017). The effectiveness of specific fire prevention measures for different population groups. *Fire Safety Journal, 91*, 1044-1050.

SCDF. (2013). *Fire Code 2013. Singapore Civil Defence Force*.

Shams, D. A. F. A. (2011). High Rise Buildings and How They Affect Countries Progression.

Stumpf, K., Knuth, D., Kietzmann, D., & Schmidt, S. (2017). Adoption of fire prevention measures – Predictors in a representative German sample. *Safety Science, 94*(Supplement C), 94-102.

Ta, A. P. D. T. L. (2009). *Managing High-Rise Residential Building In Malaysia: Where Are We?* . Paper presented at the 2ND NAPREC Conference, INSPEN, School of Social Sciences Universiti Sains Malaysia 11800 USM, Pulau Pinang.

Tharmarajan, P. A. L. (2007). *The Essential Aspects Of Fire Safety Management In High-Rise Buildings.*

Wong, K. H. L., & Xie, D. Y. (2014). Fire Safety Management Strategy of Complex Developments. *Procedia Engineering, 71*, 410-420.

Wong, S. F. (2016). *Joint Bomba Professional Workshop & Forum*.

Xin, J., & Huang, C. (2013). Fire risk analysis of residential buildings based on scenario clusters and its application in fire risk management. *Fire Safety Journal, 62*, 72-78.

Yang, Y. (2013). Tactics for Fire Prevention and Control in "Three in One" Work Houses. *Procedia Engineering, 52*, 536-540.

Yau, A., & Ho, S. K. M. (2014). Fire Risk Analysis and Optimization of Fire Prevention Management for Green Building Design and High Rise Buildings Hong Kong Experience.