EVALUATION OF RISK MANAGEMENT FRAMEWORKS FOR HOSPITALS

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Degree of Master of Science

Department of Civil Engineering

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Thesis submitted in partial fulfillment of the requirements for the degree Master of Science in Civil Engineering

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Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgment any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

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Name of the supervisor: Dr C.S.A. Siriwardana

Signature of the supervisor: …… Date: ……..……..

Abstract

Unlike disasters that arise from natural hazards, fire disasters can occur at any moment, in any place, if the proper precautions are not taken. The spreading of fire can more often cause disastrous results, such as loss of property, injuries, and death. Hospitals especially have a vulnerability to fire, considering the flammable materials present in the buildings such as medical gas, generator fuel, laboratory materials, high fire risk areas such as kitchens and generator room, a high waste generation which occurs in hospitals as well as the vulnerable people in the hospital such as patients with mobility issues. Therefore, fire risk management is essential for hospitals.

This research study focused on developing a risk management framework for hospitals focusing on fire hazards. The framework consists of two sections; a risk assessment tool that can be used to assess the fire risk performance of hospitals and a post-disaster activity list for hospitals after a fire hazard. The framework consists of three modules: design and construction, operation and maintenance, and fire hazard management. This framework can be used by hospital administrators to evaluate the current level of fire safety of the hospital. Thereby, the administration can analyze the weaknesses and take action to correct them. The post-disaster activity list contains actions related to the elements of people, buildings and critical infrastructure, hospital equipment, and material and post-disaster administrative work.

During the development and analyzing the applicability of the risk management framework, six governmental and 3 private-owned hospitals were assessed. The data collected revealed some key differences between the two types of hospitals. The private-owned hospitals showed a better level of preparedness for hospital fires as they had fire extinguishers and other fire protection systems which were updated regularly, had annual maintenance and testing of fire protection systems and annual fire training and fire drills for staff. In almost all of the surveyed government hospitals, these elements of preparedness were missing.

Keywords: safe hospital, fire safety, risk management framework, risk assessment tool, post-disaster management

Dedication

Fire exists the first in light, - And then consolidates, -

Only the chemist can disclose - Into what carbonates

-Emily Dickinson-

(1830-1886)

To my parents,

Thank you,

For dousing those physical fires, I lit in my childhood,

but also,

For kindling the fires that were my thirst for knowledge

Acknowledgments

I would like to express my heartfelt thanks to my research supervisor, Dr. Chandana Siriwardana for his guidance, suggestions, and motivation throughout the research study. His immense support allowed me to gain a wide exposure to the area of disaster risk reduction in the local and international arenas. I also express my sincere gratitude to Prof. Asoka Perera and Dr. Nimal Wijayaratna for their guidance and advice in this study.

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Thank you,

Devmini Kularatne

Table of Contents

List of Figures

List of Tables

List of Abbreviations

BBB	Build Back Better
BH	Base Hospital
DC	Design and Construction
DGH	District General Hospital
DH	Divisional Hospital
DRP	Disaster Recovery Plan
DRR	Disaster Risk Reduction
EEP	Emergency Evacuation Procedures
ERT	Emergency Response Team
FAP	Fire Action Plan
FC	Fire Commander
FEMA	Federal Emergency Management Agency
FHM	Fire Hazard Management
FRAT	Fire Risk Assessment Tool
FRMF	Fire Risk Management Framework
FRS	Fire and Rescue Services
FSC	Fire and Safety Check
GDP	Gross Domestic Product
HDMP	Hospital Disaster Management Plan
HSI	Hospital Safety Index
IRS	Incident Reporting System
NGDP	National Gross Domestic Product
NH	National Hospital

OM	Operation and Maintenance
PMCU	Primary Medical Care Unit
TH	Teaching Hospital
UNISDR	United Nations International Strategy for Disaster Reduction

1 Introduction to the Research Study

1.1 Background

The occurrence of natural hazards is a natural part of the world process. When these hazards become involved with human life, they have the tendency to turn into disasters, negatively impacting human life and causing economic and social losses. Social hazards such as social conflicts, bomb blasting, and group protests are also potential occurrences in the present-day world and can turn into violent results [1]. Biological hazards are also another possibility in the world, which could result in epidemics and pandemics such as Ebola, MERS (Middle East Respiratory Syndrome), 2009 H1N1, and the most recent Covid-19 pandemics [2], [3]. These pandemics can take a great toll on multiple facets of human society, such as healthcare, political, economic, and social-welfare systems [4].

Figure 1 shows how the disasters caused by natural hazards have affected the world in 2017 [5]. Accordingly, it can be identified that Asia is the highest affected continent. Figure 2 and Figure 3 showcase the occurrence of the disasters by disaster type and the number of deaths by disaster type in 2017 respectively [5]. From the figures, it can be seen that wildfires are of some concern.

In addition to wildfires, domestic fires are also a big problem in the world. In the 21st century, the world annually experienced 7 to 8 million fires annually which caused 500,000 to 800,000 fire injuries [6]. Fire causes around 300,000 deaths annually [7] and in addition around 11.5 million recorded cases of smoke-induced diseases [8]. In Sri Lanka also, fire is a major concern, with 5% of recorded disaster events in the country being fires between 2009 and 2019 [9]. From 1965 to 2019, fires in Sri Lanka have caused 107 deaths and 368 injuries. These fires also caused the destruction of 1996 houses and partial damage to another 1003 houses [9].

Figure 1: Number of disasters in 2017 by continent and top countries

[5]

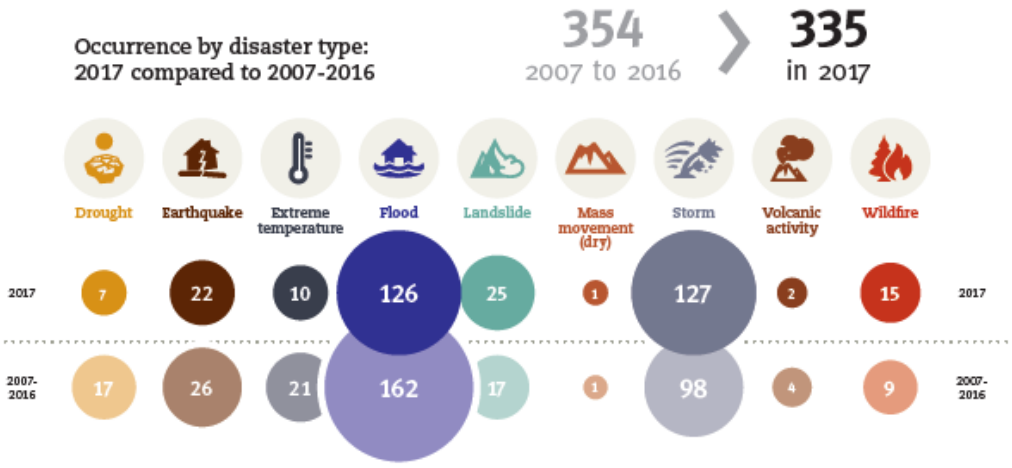

Figure 2: Occurrence by disaster type: 2017 compared to 2007-2016

[5]

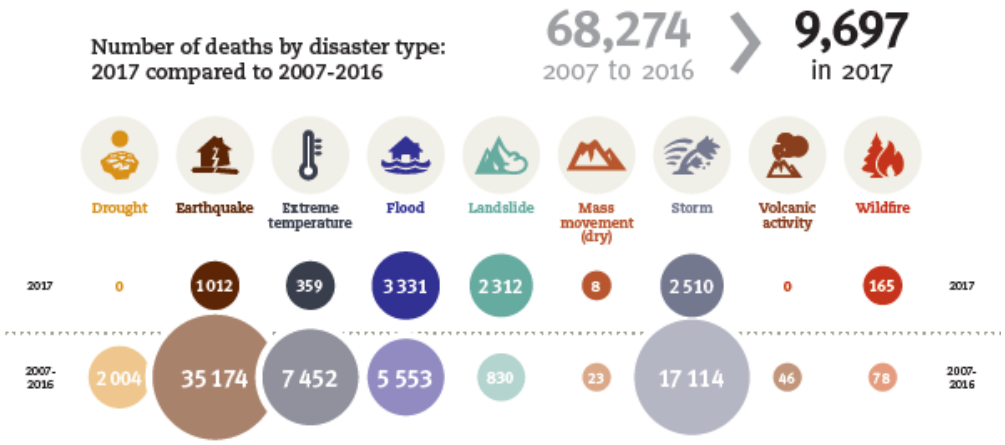

Figure 3: Number of deaths by disaster type: 2017 compared to 2007-2016

[5]

Hazards have the potential to cause disastrous results in healthcare institutes, considering the functions and people in the hospitals. Hospitals have to consider hazards that could occur inside the hospital premises as well as the hazards that could occur outside the hospital in the community. Past studies have shown that hospitals are more vulnerable to hazards that would directly impact the hospital buildings and people within them, due to the unpreparedness to face such hazards [10].

Hospitals are especially vulnerable to fire hazards as they contain substantial quantities of combustible material such as flammable chemicals and medical gases, electrical generators, and large electrical networks and they also have a high waste generation rate [11]. Hospitals must be able to reduce this vulnerability and thereby minimize the risk of fires in hospitals in order to maintain a good functioning of the hospital. This is especially needed in a country like Sri Lanka where hospitals are generally viewed as institutions that would doubly serve as a place of refuge during a disaster [12]. This need is even more valid considering the fact that the Sri Lankan government provides free healthcare to its citizens and spends nearly 3% of its Gross Domestic Product (DP) expenditure on health [13]. Prevention of potential fire hazards in hospitals will diminish any economic losses that would be made on the Sri Lankan government.

Fire is a dangerous hazard for several reasons. There is a risk of fire in any place, unlike natural hazards such as floods and landslides. In the case a fire occurs and spreads, there is a possibility that both people and property will be negatively

impacted, in ways such as injuries, deaths, and property damage. In short, fire can cause disastrous results to various aspects of society such as social aspects and economical aspects. Sri Lanka and its hospitals especially can be vulnerable to fire hazards as seen from the statistics given earlier. Therefore, it is important that the government and institutions such as hospitals take measures to minimize the risks of fire. Therefore, in this study, fire hazards were chosen as the focus as shown in Figure 4.

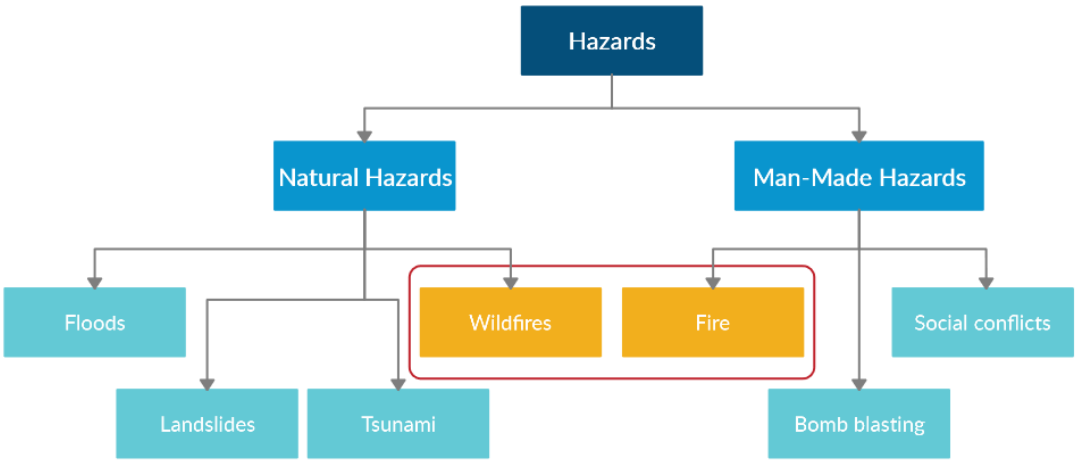

Figure 4: Selection of fire hazards

To minimize the risk of fire hazard in a hospital, first, it is necessary to identify the current risk level of the hospital and its weak points. Only then can the hospital administration take action to address those points and correct them. In order to systematically analyze the risk level of a hospital against fire hazards, a structured method is needed. The purpose of this study is to develop a comprehensive, multi-dimensional risk management framework for hospitals, focusing on fire hazards.

1.2 Thesis Question

The main question that this thesis attempts to answer is, “how can the risk level of a hospital with regards to fire hazards be measured?”. In order to be able to compare the

fire risk level of a hospital against a standard level, the method of measurement must be structured and applicable to any hospital in a uniform way.

In order to put forward a comprehensive and suitable measurement tool, the following questions need to be answered.

- What are the causes of fire hazards in hospitals?
- Who are the stakeholders with regards to a hospital fire hazard?
- What are the elements affected by a fire hazard
- What actions could be done to prevent, minimize or mitigate a hospital fire hazard?
- What action are needed for fast and complete recovery after a hospital fire hazard?

1.3 Problem Statement

Fire is a useful tool that can turn into a hazard very quickly. Fire hazards can occur at any time in any place under the right circumstances and therefore preventing the occurrence of a fire should be taken very seriously. Hospitals are extremely susceptible to fire hazards due to the activities carried out within it and the various types of flammable materials used by the hospital staff. It is necessary that corrective and preventative actions are taken by the hospital to minimize the risk of fire. For this, a fire risk assessment tool that can assess each and every aspect of a hospital concerning fire hazards is needed. This will allow hospital administrators to identify the current risk level of the hospital regarding fire and carry out improvements needed.

1.4 Scope of the Study

In this study, the risk assessment tool will be developed focusing on hospitals in Sri Lanka. Here, both government-owned hospitals and medium and large-scale private-owned hospitals will be considered. For the tool to be multi-dimensional, the assessment will include criteria regarding design and construction, operation and maintenance, and hospital management.

1.5 Research Objectives

The main final objective of the research study was to develop a comprehensive multi-dimensional risk management framework for hospitals focusing on fire hazards. To achieve this, the following specific objectives have been defined.

1. To identify the causes of fire in hospitals
2. To develop the Fire Risk Management Framework (FRMF) structure
3. To develop the Fire Risk Management Framework for hospitals
    a. Fire Risk Assessment Tool (FRAT) for hospitals
    b. List of post-disaster activities for a hospital after a fire hazard

1.6 Outcomes

The final outcome of this research study is the Fire Risk Management Framework for hospitals (focusing on fire hazards) consisting of the Fire Risk Assessment Tool (FRAT) and the post-disaster activities list. The FRAT can be used to quantify the risk level of a hospital regarding fire hazards. The post-disaster activity list can be used by hospital administrative staff after a fire hazard as an initial starting point which can be modified as suitable for the size and nature of the fire.

2 Literature Review

2.1 Disaster Risk Terminology

2.1.1 Hazard

A hazard is the possible occurrence of a future event that can have a negative effect on vulnerable and exposed elements [14].

2.1.2 Disaster

A disaster can be defined as the exposure of humans to a hazard which will leave negative impacts and losses in aspects of humans, property, economy, and environment due to the vulnerability and lack of capacity of the community [15]

2.1.3 Exposure

Exposure can be given as a measure of elements that are present in a hazard zone. These elements can include people, property, and systems [16], [17].

2.1.4 Preparedness

The Federal Emergency Management Agency (FEMA) has defined preparedness as a cycle containing the phases of planning, organizing, training, equipping, evaluation, and taking corrective actions in order to have a good level of coordination during responding to an incident [18].

According to the United Nations, the knowledge and capacity of governments, response, and recovery organizations, communities, and individuals to anticipate, effectively face, and recover from disasters can be denoted as preparedness [19].

2.1.5 Capacity

Capacity is the total of the strengths, attributes, and resources possessed by an individual, community, or organization which can be used to achieve the necessary goals [15].

2.1.6 Vulnerability

Vulnerability is the possibility of the exposed elements suffering adverse effects due to the hazard [16].

2.1.7 Risk

Risk can be introduced as the product of the probability that an event may occur and its negative results [15].

Risk has also been defined through various equations (1), (2), and (3) as given below.

$$\text{Risk} = \frac{\text{Hazard}}{\text{Safeguards}} \text{ [20]} \quad (1)$$

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability} \text{ [17]} \quad (2)$$

$$\text{Risk} = \frac{\text{Hazard} \times \text{Exposure}}{\text{Capacity}} \text{ [21]} \quad (3)$$

2.1.8 Disaster Resilience

According to the United Nations International Strategy for Disaster Reduction, disaster resilience in the ability of a system in the face of a hazard to resist, absorb, accommodate, adapt to, transform and recover in an efficient way [15].

Manyena (2006) describes resilience as the ability to effectively cope with a hazard in such a way that the system can bounce back to its original state after the hazard [22].

2.1.9 Safe Hospital

The World Health Organization has defined a Safe Hospital as a healthcare service that can continue functioning at maximum capacity safely before, during, and immediately after a disaster [23].

2.2 Disaster Profile in Sri Lanka

Sri Lanka annually faces a range of hazards causing disasters, natural, social, and biological. Most of these hazards are hydro-meteorological hazards such as floods, heavy rains, and landslides. However, there are also other disasters such as fire, lightning, animal attacks, and traffic accidents. The hazard profile of Sri Lanka between the years of 2009 and 2019 has been depicted in Figure 5.

According to the chart, 4% of the recorded number of disaster events in Sri Lanka between 2009 and 2019 have been building fires and another 1% have been forest fires [9].

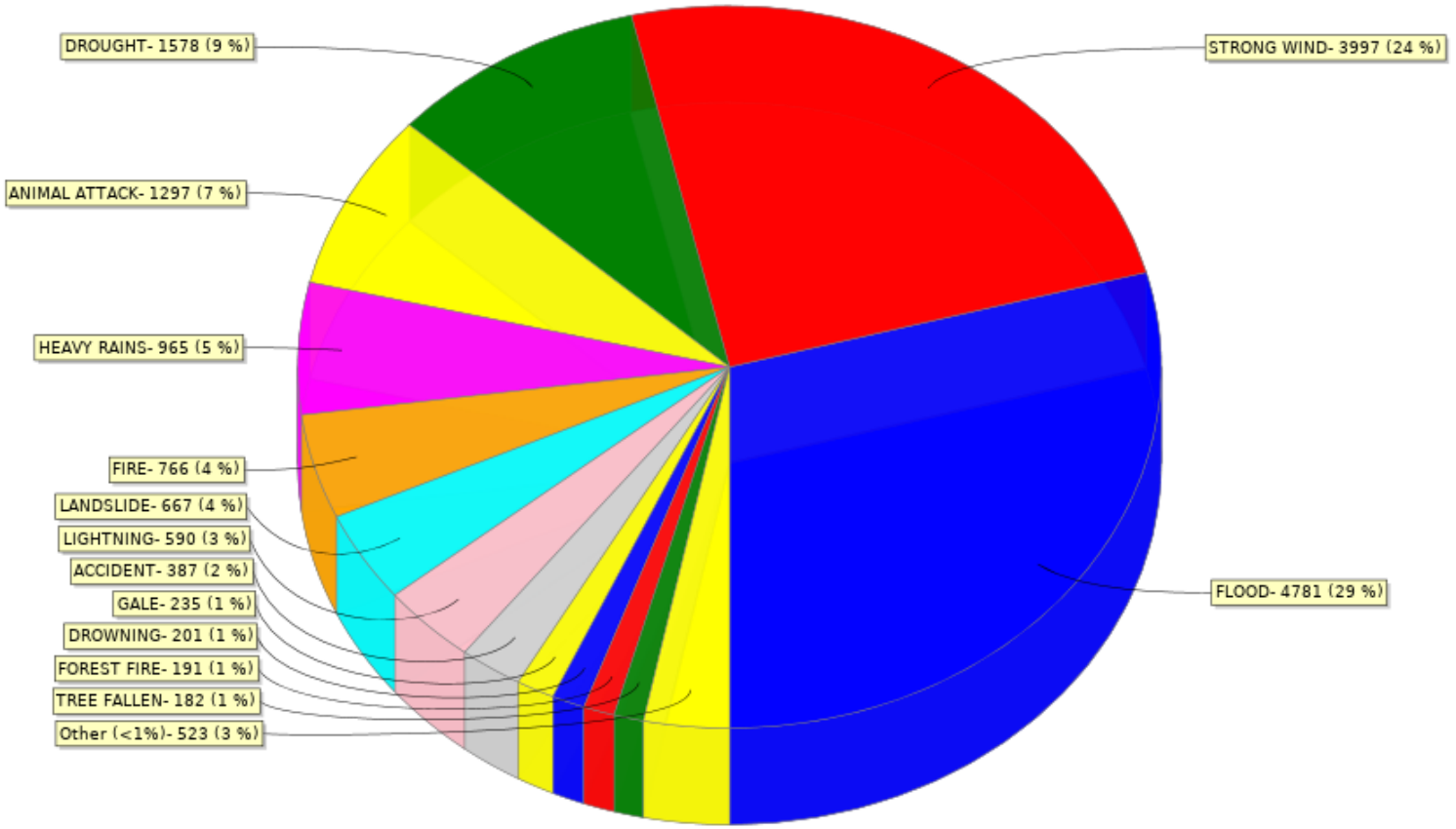

Figure 5: Number of records of disasters in Sri Lanka (2008 January – 2020 April)

[24]

2.3 Fire

2.3.1 Introduction to Fire

Fire can be defined as a chemical process (oxidation) that emits heat, smoke, and light. To complete this process, the components needed are fuel, heat, and oxygen. If any of those components are removed from the process, the fire will be extinguished. These three components of fuel, heat, and oxygen along with the uninhibited chain reaction which provides heat to help maintain the fire make up the fire tetrahedron [25]. This is shown below in Figure 6. Fire can be classified according to the type of fuel: solid materials (Class A), liquids or liquefiable solids (Class B), gases (Class C), metals (Class D), live electrical apparatus (Class E) and cooking oils or fats (Class F) [26].

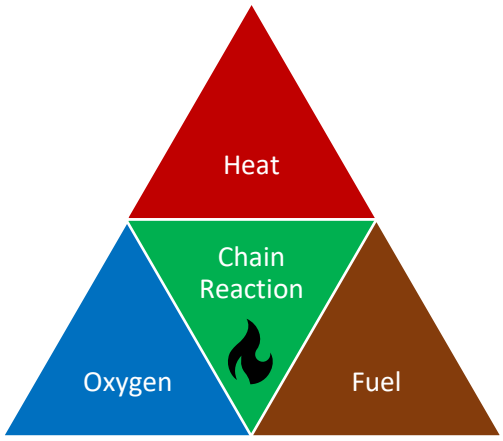

Figure 6: Fire Tetrahedron

There are 4 stages of fire. The first is ignition, where the components of fire are joined in the chemical process and can be easily controlled. The next stage is growth, where the fire uses the heat of the flame to ignite other fuel sources in the vicinity [25]. The rate of temperature increase in this period can be given by equation (4) [27], [28].

$$T_{(t)} = T_{(0)} + \log_{10}(8t + 1) \quad (4)$$

In this equation, T represents temperature in Celsius degrees and t represents time.

The third stage is the fully developed fire, where the fire has spread over all the fuel and is consuming oxygen rapidly. The temperature peaks in this stage. The final stage is decay or burnout, where the fire gets less intense, and the temperature decreases [25]. These stages can be understood clearly from Figure 7.

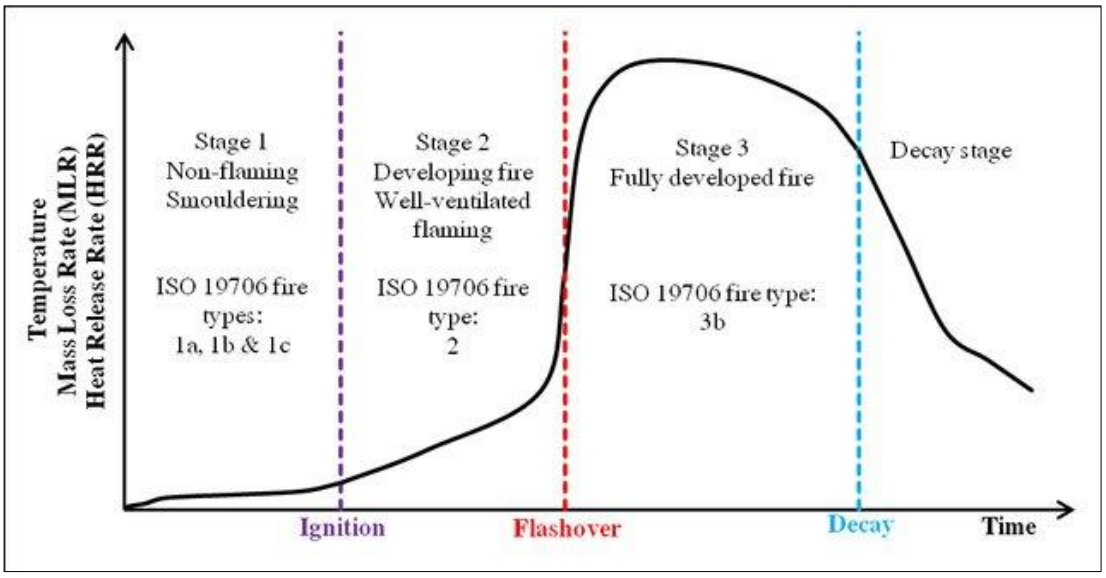

Figure 7: Phases in the development of a fire

Adapted from "What Kills People in a Fire? Heat or Smoke?," by Alarifi, Phylaktou and Andrews, 2016, presented at the 9th Saudi Students Conference, Birmingham, UK [29]

Fire can spread in three kinds of ways: conduction, convection, and radiation. Conduction is the transfer of heat through contact between materials. Convection is when fluids flow from a high heat area to a cool area. Radiation is the transfer of heat through electromagnetic waves [25].

2.3.2 Negative Effects of Fire

Fire, the very first discovery of humans, can be an extremely useful tool in a controlled environment. However, it can spiral out of control very quickly and easily, causing serious injuries, deaths, and loss of property. Usually, the losses due to fire can be categorized as either direct losses or indirect losses. Direct losses can include lives and property directly affected. On the other hand, indirect losses can mean consequential losses such as loss of production and loss of trade. Past statistics have shown that the total losses due to fire can be thrice as much as the direct losses [30].

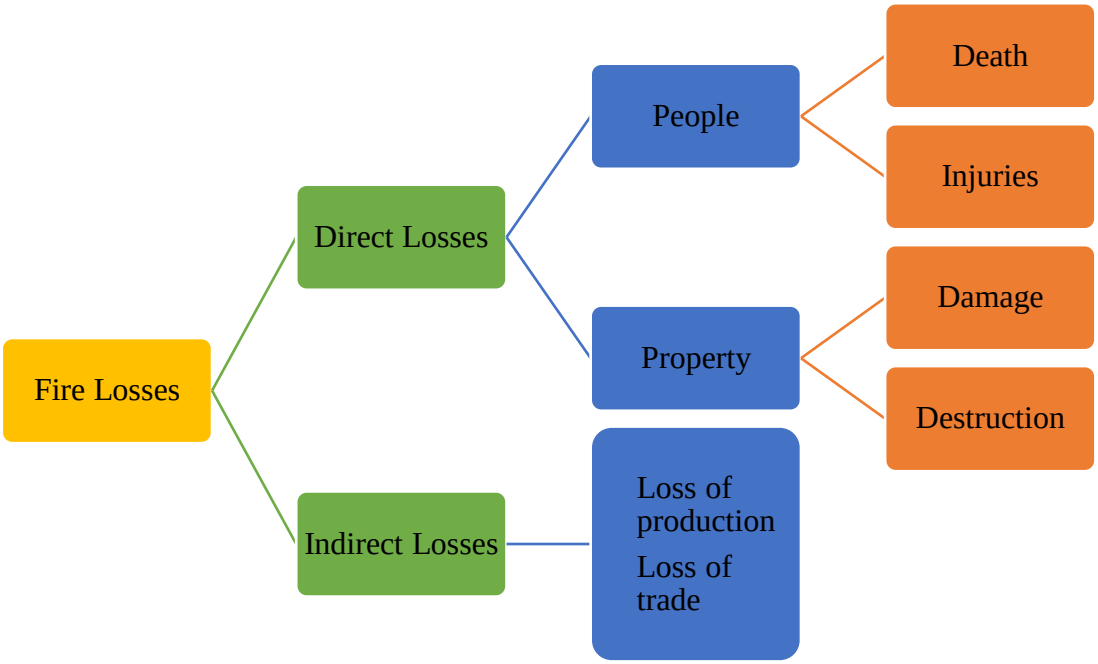

Figure 8: Breakdown of fire-related losses

Fire is the cause of a large number of deaths annually. Looking at published statistics in developed countries, it can be seen that the numbers vary from a low number of 0.02 deaths per 100,000 population in Singapore to a high value of 2.03 deaths per 100,000 population in Finland between 2008 and 2010.

The low number of fire fatalities in Singapore can be attributed to the reduction of fires in residential areas [31]. This is due to factors such as the public education efforts of the government, an increased number of building owners following fire safety rules, reduction of fire safety offenses, and an increase in compliance of citizens regarding fire regulations [32].

In Finland, a large number of fire-caused deaths have been caused by smoking, followed by burn injuries. The country has experienced an increase in deliberately caused fires in low-income neighborhoods. This has caused an increase in low-income victims in the country due to fires [33]. Another cause for fatalities is intoxication during accidental fires. 77 people died due to accidental fires in Finland in 2014 and over half of these people were intoxicated. There have also been people who had used fire as a method of suicide in the country [34].

The changes in the per capita figures in different countries have been attributed partly to the changing population figures in these countries as well as the environmental factors such as the probability for wildfires in the areas [35].

When regarding fire-related fatalities, it has been observed that a majority of the fatalities have been male. There is also an increase in the risk of fatality for elderly people, people with reduced mobility, and people with mental disorders. Other factors that increase the risk of deaths in a fire are smoking, use of drugs and alcohol, and living alone. Some of the main causes of fatal fires in European countries, the United Kingdom and the United States of America have been identified as smoking, electrical causes, carelessness with open fire, cooking, and fire originating in textiles [36], [37].

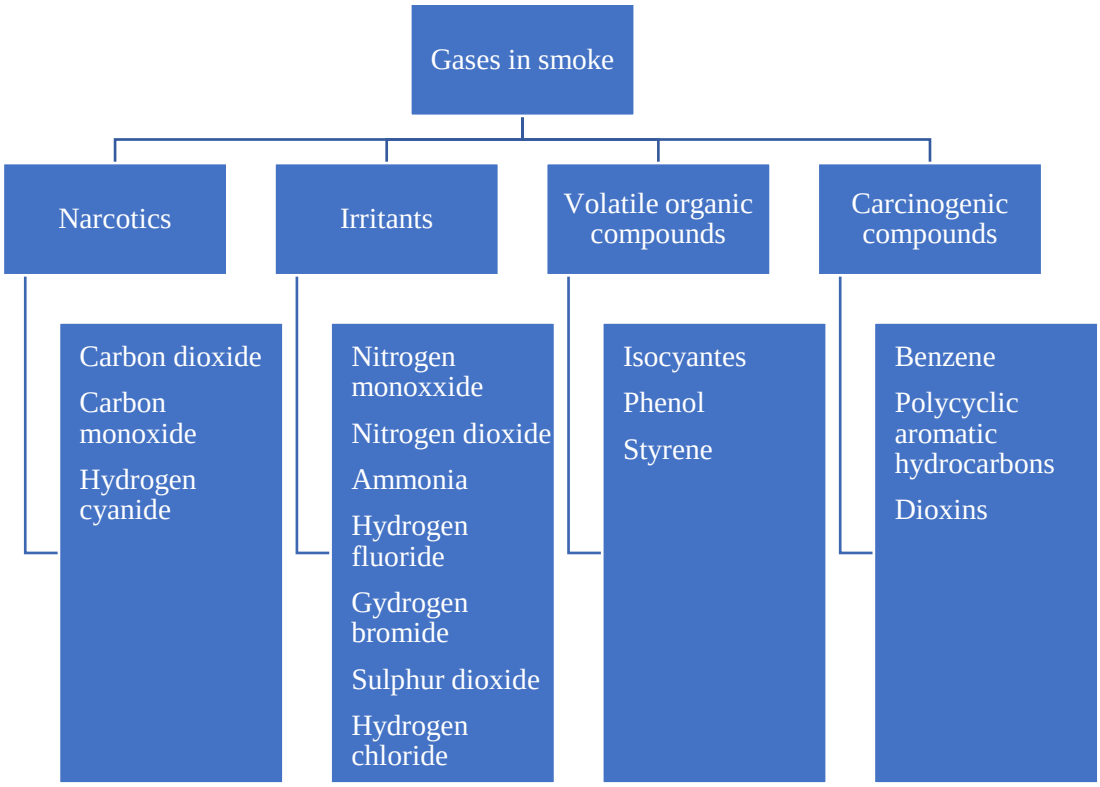

Figure 9: Gases in smoke

The danger of fire is expanded by the negative properties of smoke, which is the byproduct of fire. According to a series of large-scale experiments done by Blomqvist in 2005 revealed that smoke includes gases with various negative effects, as shown in Figure 9 [8]. Smoke is the cause of about 1% of the diseases in the world [38], [39].

In 2002, out of the 11.5 million reported cases of diseases around the world, 6.5 million cases were from South East Asia [7].

There is a marked difference in the impact of fires in developed countries and developing countries. The losses due to fires in developing countries are much greater than in developed countries, both in terms of urban fires and wildfires [40], [41]. Actions taken by developed countries have seen a reduction in fire hazards. Developed countries have seen an increased use of smoke alarms and sprinkler systems. For example, by 1998, 95% of the residences in the USA had smoke alarms installed. There has also been legislature introduced to promote fire safety. For example, the introduction of the Furniture and Furnishings Regulations in 1988 which requires ignition resistance of filling and covering material of furniture has saved up to 1860 lives between 1988 and 1997 [37]. When smoking was observed to be a major cause of accidental fires, self-extinguishing cigarettes were developed and endorsed by the governments of these countries [33], [42].

The risk of fires in developing countries is increased due to factors such as the increase of population in urban areas, increase of construction activities, the lack of enforcement of safety regulations, unplanned growth of cities, lack of attention to fire regulations by building contractors, and large traffic volumes on roads. The lack of sufficient firefighting training and equipment also contributes to this high risk [41]. For example, a fire erupted in a high rise building in Dhaka, Bangladesh in 2019 killing 25 people. The reasons for the high number of fatalities have been named as the lack of proper fire exits, insufficient firefighting equipment violation of building codes [43]. Another fire incident in 2019 in a bag factory in New Delhi, India killed over 40 people. The post-disaster investigations revealed that the factory had been operating without a fire license [44].

Sri Lanka, similar to other countries, experiences fires, which can be residential fires, industrial fires, or forest fires. Figure 10 showcases the building fires and forest fires that occurred in Sri Lanka between 2009 and 2019. These fires have made a considerable impact on the country. Some of these fire incidents include forest fires in Ella, started by residents clearing land for agriculture purposes, fire at a construction site in Bambalapitiya in February 2020, and fire at the Teaching Hospital Kurunegala

[45]–[47]. Fires were responsible for 1% of all disaster-related deaths and 3% of disaster-related injuries in the country between 2009 and 2019. The statistics of deaths due to fires in the past 11 years have been shown in Figure 11. The highest number of recorded fire fatalities was 4 in both 2016 and 2017 and the lowest was 1 in 2009, 2012, 2014, and 2019.

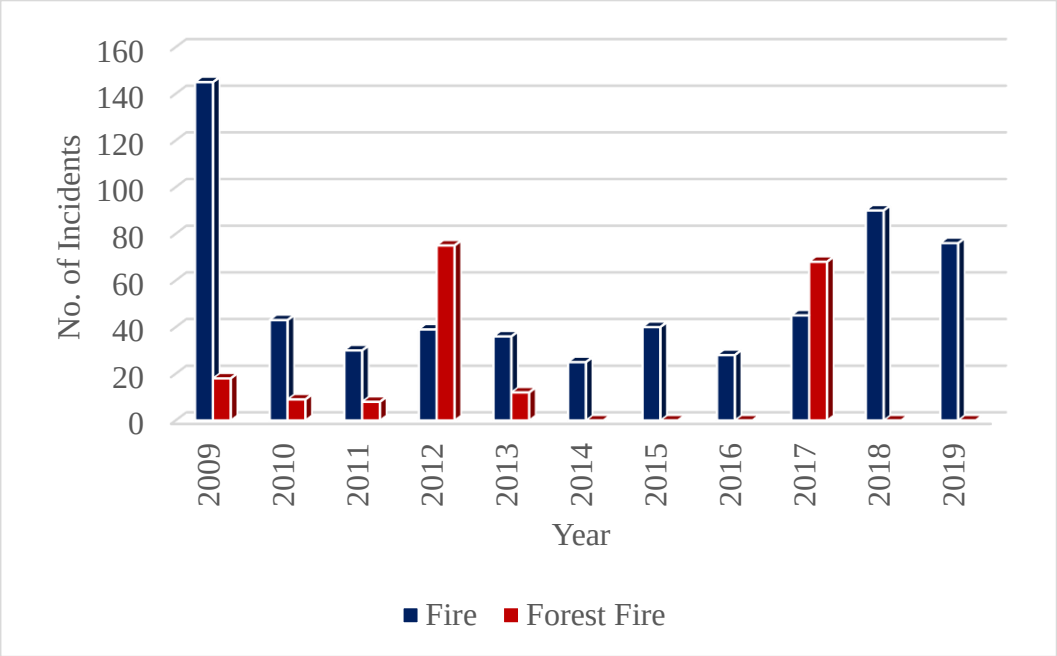

Figure 10: Fire incidents in Sri Lanka (2009-2019)

[9]

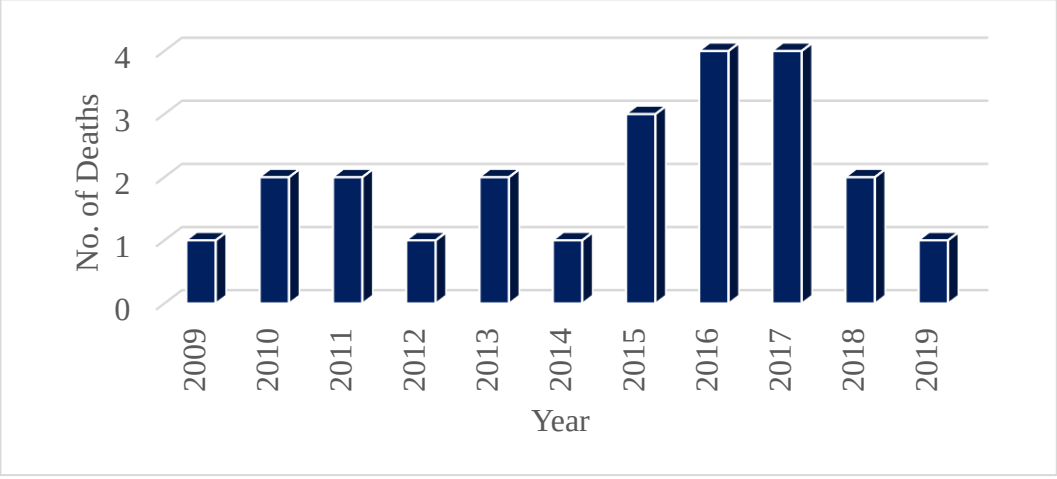

Figure 11: Deaths due to fire incidents in Sri Lanka (2009-2019)

[9]

In addition to the loss and injury of human life, fire has also impacted property of Sri Lankan citizens. The statistics of houses that were destroyed completely and houses that were damaged due to fire are shown in Figure 12 and Figure 13. As can be seen, the highest number of houses destroyed in a year was 194 in 2013, followed by 156 in 2009. The lowest recorded number of residences destructed was 4 in 2012 and the second-lowest was in 2011 when 10 houses were destroyed. Considering houses that were partially damaged in a fire, the highest number of recorded house damages was 116 in 2011 followed by 67 in 2009. The lowest number of damaged houses in a year was 12 in 2013 and the second-lowest was 13 in 2012. In the 11 years from 2009 to 2019, an average of 71 houses were destroyed and another 39 houses were partially damaged annually [9].

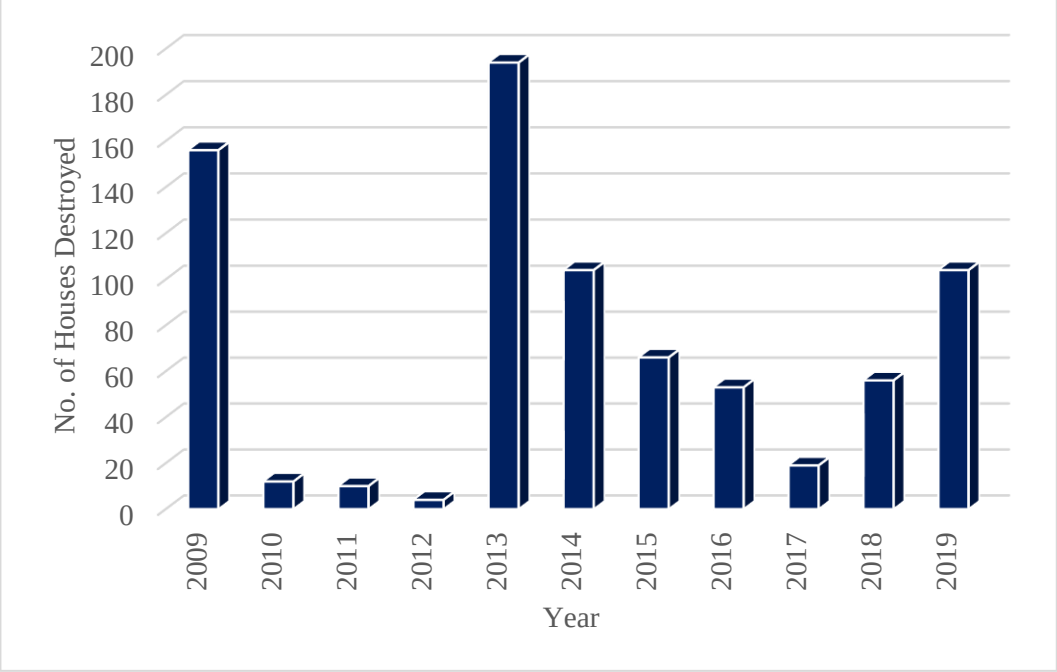

Figure 12: Houses destroyed due to fire incidents in Sri Lanka (2009-2019) [9]

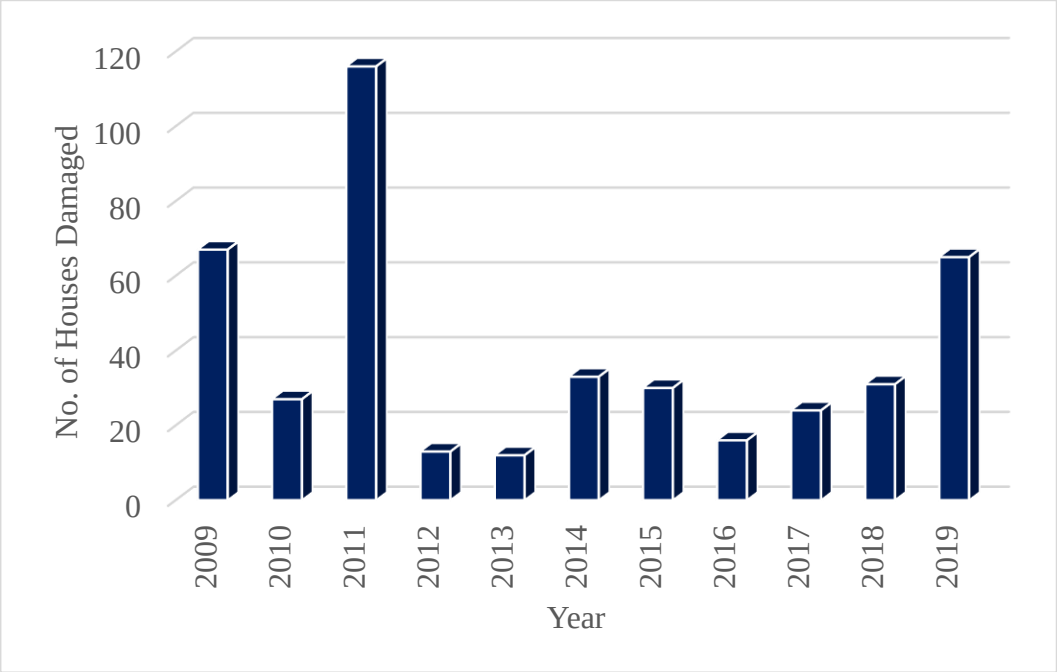

Figure 13: Houses damaged due to fire incidents in Sri Lanka (2009-2019)

[9]

A study was done by Lin et al. (2009) in Taiwan regarding fire losses in residential buildings identified the main factors which affect the damage to life and property [48]. These factors are given below.

1. Time of fire occurrence
2. Degree of severity
3. Level of difficulty in fire escape
4. Time taken for the Fire and Rescue Service (FRS) to control the fire
5. The FRS forces dispatched
6. Structure of the partitions
7. Condition of escape routes
8. Accessibility and conditions for firefighting

2.3.3 Economic Losses of Fire Hazards

Fire disasters also cause high economic damages to both individuals and communities. Available statistics show that the National Gross Domestic Product (NGDP) spent for direct fire losses range from 0.02% in Hungary (2009 - 2010) to 0.22% in Norway (2003 – 2005) [35]. The statistics of direct economic losses and per capita deaths for some developed countries have been shown below in Figure 14. As can be seen from the figure, the losses to life and losses to property cannot be linearly correlated.

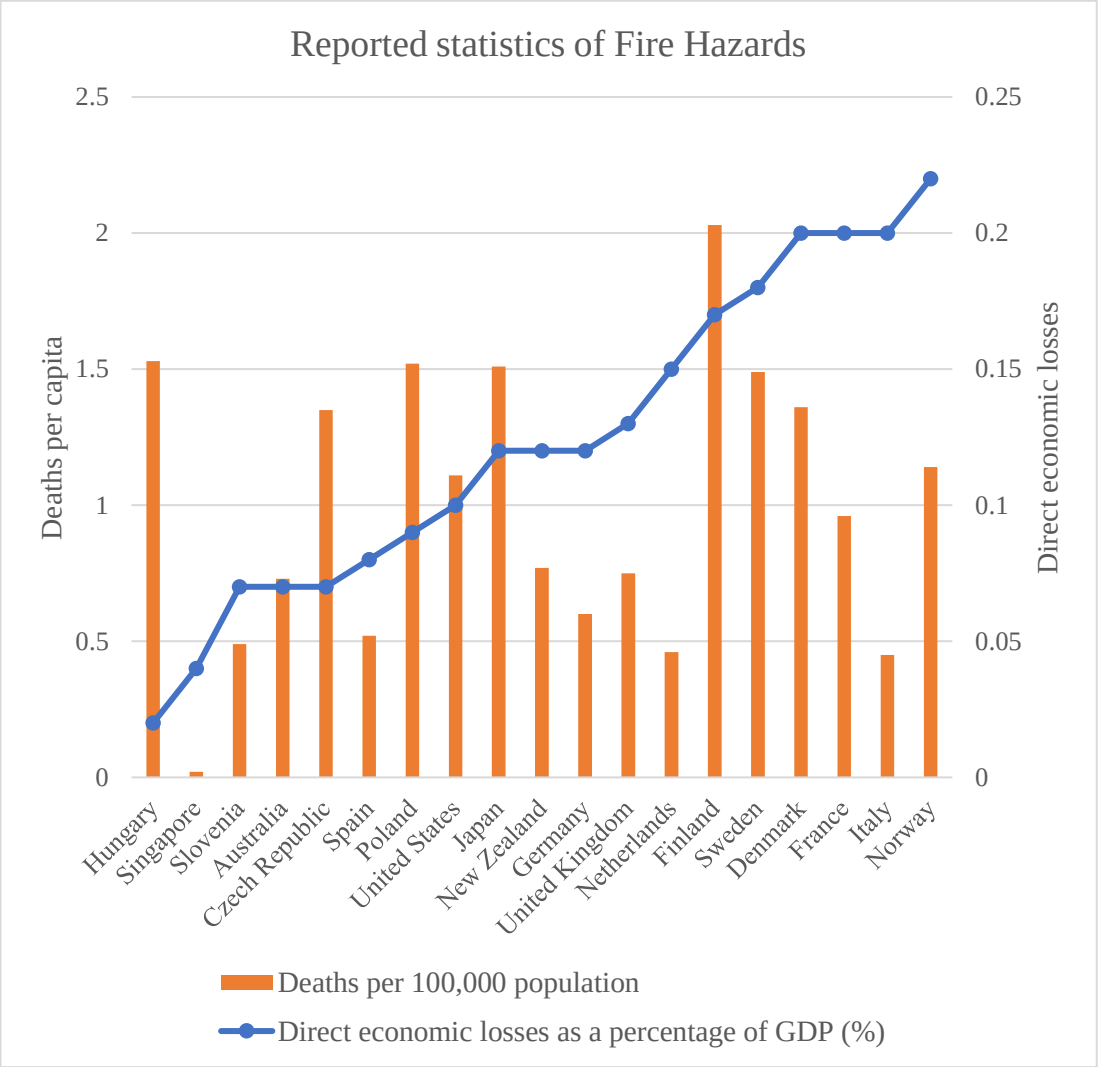

Figure 14: Reported statistics of fire hazards

[35]

It has been noted that over time, deaths due to fire has reduced, but the costs of fire have increased gradually [49]. Usually, a high number of fires are small fires and only a small number of fires are large fires. Therefore, the majority of costs are incurred due to small scale fires [50]. However, large fires still account for around 30% of the total fire economic losses [30].

Fire hazards also incur other costs apart from direct and indirect losses. There are the costs due to government-run fire brigade services, administrative work related to fire protection, administrative costs of fire insurance companies, and fire protection costs. Then there are also costs due to the enforcement of fire safety and the development of safety standards, codes, and regulations done by governmental organizations [30].

2.4 Healthcare Institutions in Sri Lanka

Hospitals in Sri Lanka are of two types according to the ownership: government-owned hospitals and private-owned hospitals. Government-owned hospitals again come in different levels, ranging from National Hospitals to Primary Medical Care Units. Similarly, private owned hospitals also vary from large-scale hospitals to small private medical practice institutions. The variation of these different types of healthcare facilities in Sri Lanka can be seen in Figure 15.

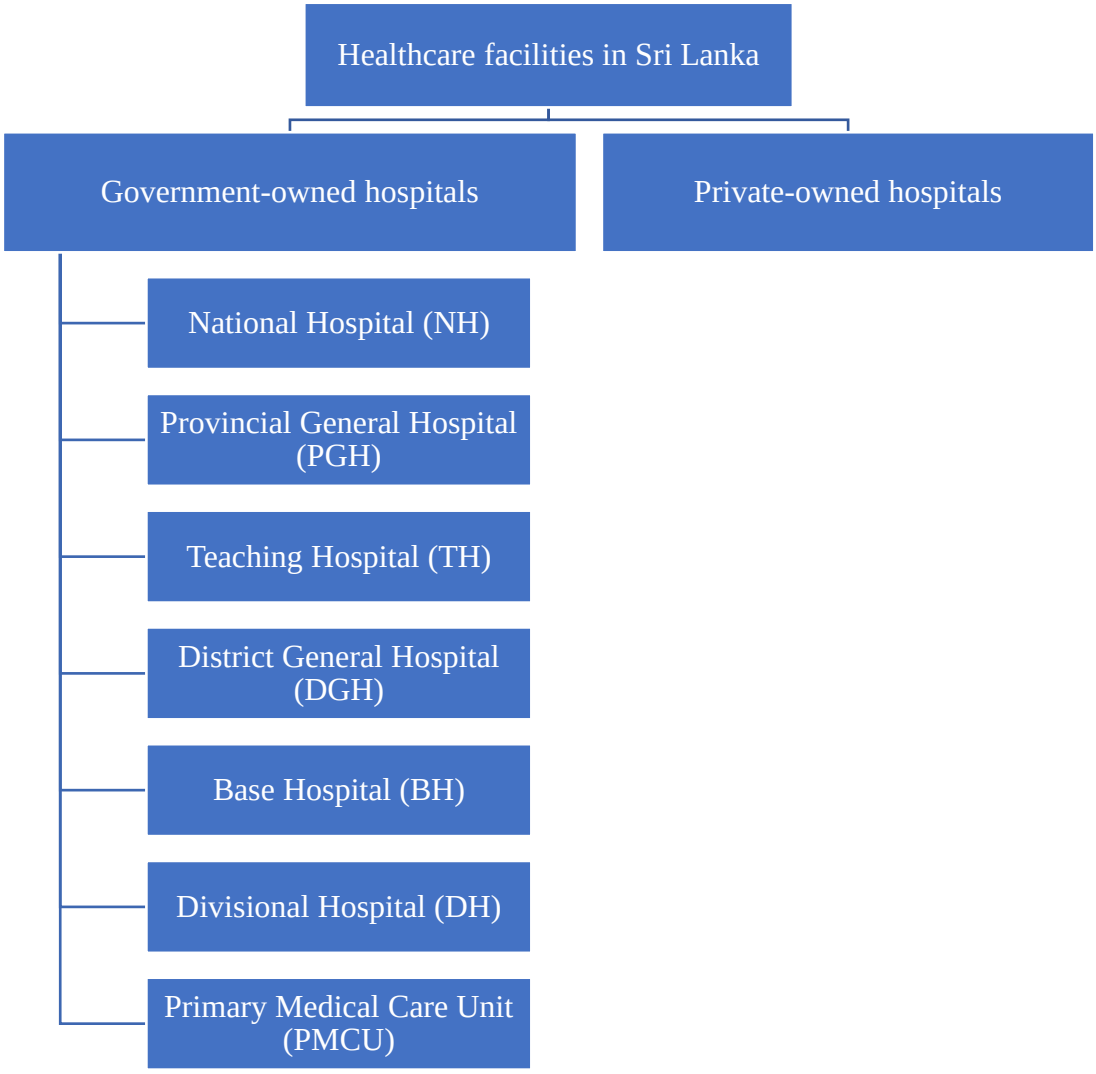

Figure 15: Different types of hospital types in Sri Lanka

The different types of government hospitals vary in the types of units available in each of them and the services they offer.

Table 1: Types of government hospitals in Sri Lanka and the units in them

Units	Above BH Level					Below BH Level	
	NH	TH	PGH	DGH	BH	DH	PMCU
Medical ward	✔	✔	✔	✔	✔	✔	✔
Surgical ward	✔	✔	✔	✔	✔	✔	
Maternity ward	✔	✔	✔	✔	✔		
Labor room	✔	✔	✔	✔	✔		
Premature Baby Unit	✔	✔	✔	✔	✔		
Neonatal Intensive Care Unit	✔	✔	✔	✔	✔		
Intensive Care Unit	✔	✔	✔	✔	✔		
Operating Theatre	✔	✔	✔	✔	✔		
Pediatric ward	✔	✔	✔	✔	✔		
Dermatology unit	✔	✔	✔	✔			
Radiology unit	✔	✔	✔	✔			
Psychiatric unit	✔	✔	✔	✔	✔	✔	

Critical units in a hospital during a disaster have been defined as units containing the most vulnerable patients who cannot be evacuated easily during a crisis. These units are given below [51].

- Maternity Ward
- Labor Room
- Premature Baby Unit
- Neonatal Intensive Care Unit
- Intensive Care Unit
- Operating Theatre
- Pediatric Unit

2.5 Disaster Risk in Hospitals

Hospitals are complex systems, with multiple activities functioning within it and hosting a large range of population which includes medical and non-medical workers, hospital patients, and visitors. The complexity of hospitals is often mistaken to represent the hospital as an individual entity that can operate without depending on external resources. However, in reality, hospitals are not isolated systems and rely on their communities as much as the communities rely on the hospitals [10].

Hospitals are similar to any other institution in the fact that they have equal potential to be affected by disasters and emergencies. Disasters and emergencies possess the ability to highlight the weaknesses and vulnerabilities of systems, structures, processes, and people [52]. Disasters can cause a higher demand for healthcare services and thereby depreciate the functionality and safety of hospitals [53]. In terms of disasters and emergencies relevant to hospitals, there are three types: where the hospital itself is affected, where the catchment community of the hospital is affected, and where both the hospitals and its catchment community are affected [52]. The catchment community area of a hospital can be defined as the area housing the population to which it provides healthcare services [54]. Case studies in the recent past have revealed that hospitals in Sri Lanka are well prepared for disasters that could occur outside the hospital premises, in the community, such as mass casualty incidents. However, the hospitals are not similarly prepared for disasters that could occur within the hospital premises, such as floods, landslides, and fires [10].

This unpreparedness could be fatal in the situation of a disaster as a large portion of the hospital is vulnerable to due poor health conditions. Therefore, the administrative officials of hospitals must understand that preparedness to look after people with chronic health conditions is key in disaster preparedness [55].

2.6 Fire Hazards in Hospitals

2.6.1 Risk of Fires in Hospitals

The risk of fires in buildings depends on the characteristics of the building such as height, structure, and diverse function [56]. The potential for a fire starting in a building also depends on the nature of ignition sources present in the building as well as the quantity of them [57]. This makes the risk of fires in hospitals very high considering the various functions being carried out in the buildings and the various hazardous material present on the premises. It must also be noted that hospitals contain some of the most vulnerable of the population, who will lack the ability to evacuate quickly as possible in the case of an emergency due to their limited mobility [58]. This makes emergency evacuation difficult [59].

After a fire starts, there is also a high risk for the fire and resulting smoke to spread, as medical pipelines often break compartmentation. Many hospitals require medical gas supply throughout the building meaning that pipelines need to be laid throughout. This means there will be an additional supply of flammable gases such as oxygen. Hospitals also have a high number of medical equipment that operates at all times, drawing a high amount of electricity. These factors increase the risk of fires in hospitals [59]

The magnitude of the risk of fires in hospitals and the disastrous results that ensue if the fires are not extinguished quickly and safely can be seen from the following examples. The AMRI Hospital in Calcutta, India experienced a fire caused by a short circuit in the basement in 2011. This caused the deaths of 89 people [60], [61]. Another fire incident was caused in the Ramenskyon Psychiatric Hospital in Moscow, Russia caused by a smoking incident in 2013. This again caused 38. deaths [62]. The fire hazard in the Royal Marsden Hospital in England in 2008 caused damages worth GB 500 million at the time [63]. A fire was caused in the Anuradhapura Teaching Hospital in Sri Lanka in 2014 during the installation of an MRI Scan machine. This caused the machine, which was worth LKR 250 million, to be destroyed [64].

Historical evidence shows that hospital buildings are highly susceptible to fire hazards. In the aftermath, they leave high losses in human life as well as economy-wise. This

proves that there is a need for hospitals to be pro-active and prepared to face such fire hazards.

2.6.2 Causes of Fire in Hospitals

2.6.2.1 Past Studies

Looking at the statistics of fire incidents that have occurred in the past, the number of small fires is in the majority. Respectively, the number of large-scale fires is minor. In the United States of America (USA), only 4% of fires managed to spread from the room of origin [65].

Taking preventative action is one of the best ways to reduce the risk of fire hazards in any place. To do this, the areas of high fire risk must be identified. By identifying the causes of fire in hospitals, the administrative officials in the hospitals can take suitable actions to reduce the risk.

In the USA, there was an average of annual 5750 reported fires in hospitals in the period of 2011 to 2015. The majority of these fires occurred in nursing homes (48%). 20% of the fires occurred in hospitals, 22% occurred in mental health facilities and the other 11% occurred in clinics or doctors' offices [65]. It was observed that the leading cause of fires was cooking equipment, being responsible for 66% of the fires. However, the direct losses due to cooking equipment were 3% of all the fires. The highest amount of direct losses was due to electrical distribution and lighting equipment. This can be seen comprehensively illustrated in Figure 16.

In the Netherlands, healthcare institutions have experienced a steady increase in fires since 2000. Dutch healthcare systems experienced 1000 fire accidents in 2013. According to Hoondert (2017), the most common cause of fires is the misuse of hospital equipment or faulty equipment. Other major causes are arson, smoking, incendiary work, and children playing with fire. The statistics regarding this have been illustrated in Figure 17. It has been noted that the low number of fires due to smoking could be because smoking in hospitals is not allowed [66].

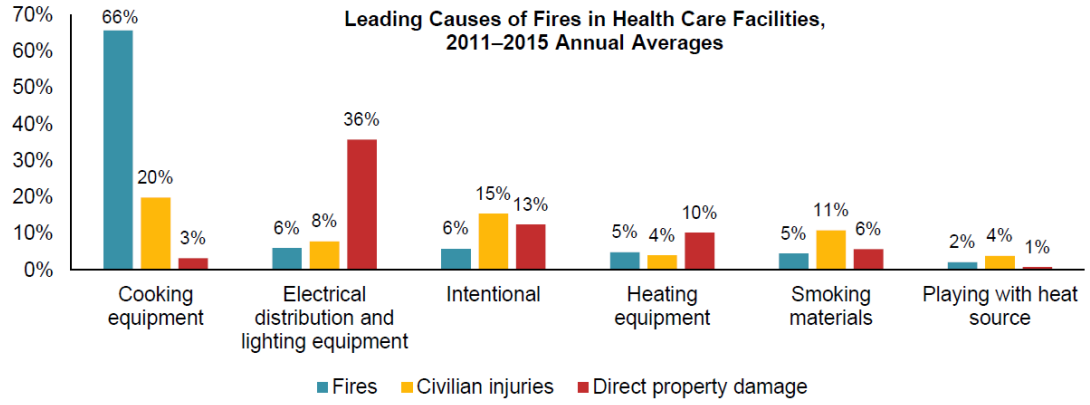

Figure 16: Causes of fire in healthcare facilities in the USA

[65]

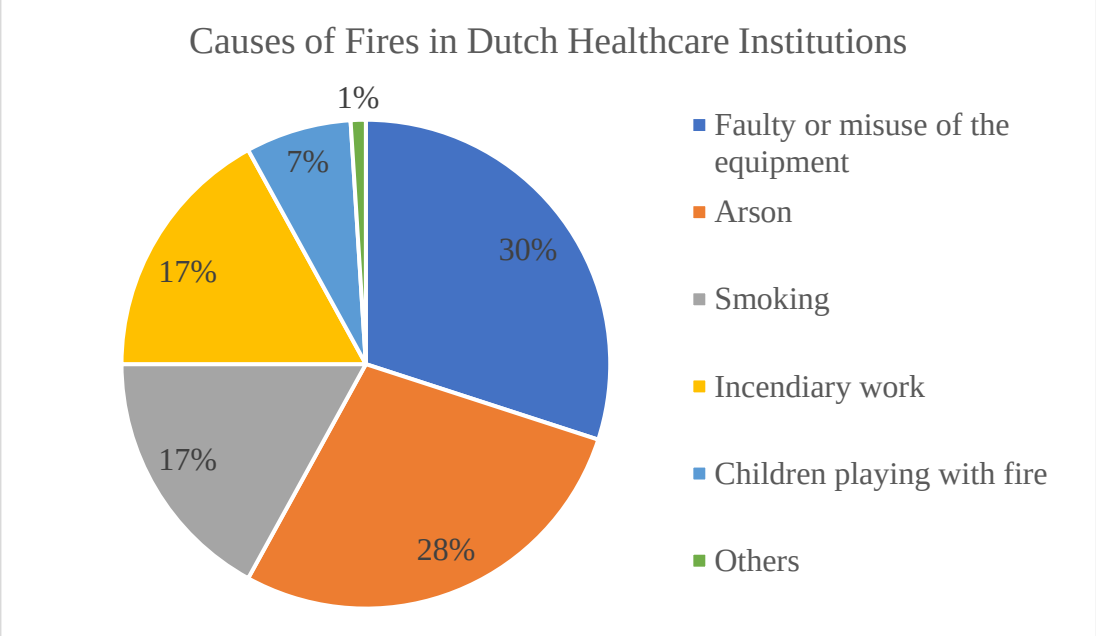

Figure 17: Causes of fires in Dutch healthcare institutions (2004-2013)

Adapted from "State of the art fire safety concept for evacuation of different types of vulnerable patients in Dutch hospitals," by Hoondert, 2017, Delft University of Technology [66]

A study done in India has revealed that a major cause for fires in hospitals is the high oxygen enrichment in the oxygen. Due to the constant use of oxygen gas in areas of the hospitals such as the Intensive Care Unit (ICU), Neonatal Intensive Care Unit (NICU), and Operating Theatre (OR), hospitals can have an above-average oxygen

concentration in the atmosphere. Many hospital fires in India have also been started due to problems in the electrical network and air conditioners have been the starting point of many hospital fires [67].

2.6.2.2 Study of a Set of Major Hospital Fire Incidents

A sample of 46 fires in various hospitals around the world that caused major losses in terms of human lives and hospital property that were disastrous to the community as well as the hospital were considered. A portion of the hospital fires in this sample set affected human lives in terms of fire injuries such as burns and smoke inhalation and fatalities. Some fires were also responsible for the evacuation of hospital patients who were in critical states. The other fires in the sample set had caused high economical losses in terms of partial and complete damages to hospital buildings, critical infrastructure systems, medical equipment, and medical supplies and loss of hospital services to the community.

The hospital fires in the sample set are given in Table 2.

Table 2: Details of hospital fires in the sample

Hospital	Country	Time of Fire	Cause of Fire	Losses and Other Results*	Reference
Beijing Children's Hospital	China	2nd July 2003	Construction work	Fire spread from underground parking to above ground	[68]
Peking Union Medical College Hospital	China	26th October 2000	Construction work	3 Deaths, 6 injured	[69]
Shanxi Hospital	China	11th April 2006	Unsafe exposure of flammable material to high heat	30 Deaths, 200 injured	[70]
City Central Hospital	China	16th December 2006	Electric fire	39 Deaths	[71]
SUM Hospital	India	17th October 2016	Not disclosed/identified	Over 22 deaths, over 100 injured	[72]
AMRI Hospital	India	9th December 2011	Electric fire	89 Deaths	[61], [73]
Tangerang Hospital	Indonesia	25th February 2019	Electric fire	156 Patients evacuated	[74]
Abe Orthopaedic Hospital	Japan	11th October 2013	Not disclosed/identified	10 Deaths	[75]
Tokyo Medical University Hospital	Japan	April 2016	Unsafe exposure of flammable material to high heat	1 Seriously injured	[76]
Sarawak General Hospital	Malaysia	16th February 2014	Construction work	1 Death, over 150 patients evacuated	[77]
A Manila Suburban Hospital	Philippines	16th May 1998	Electric fire	22 Deaths	[78], [79]
Sejong Hospital	South Korea	26th January 2018	Electric fire	37 Deaths, 130 injured	[80], [81]
Anuradhapura Teaching Hospital	Sri Lanka	3rd March 2019	Arson	USD 35,000 was stolen	[82]
Anuradhapura Teaching Hospital	Sri Lanka	20th November 2014	Equipment overheating	Equipment worth USD 2 million destroyed	[64]
Lady Ridgeway Hospital	Sri Lanka	21st April 2018	Electric fire	Damage to building	[83]

Kalmunai Base Hospital	Sri Lanka	22nd May 2018	Not disclosed/identified	Damage to chemical store, medical gear and drugs	[84]
Leprosy Hospital Manthivu	Sri Lanka	8th September 2009	Wildfire	Buildings were damaged	[85]
Walasmulla Hospital	Sri Lanka	2nd January 2018	Not disclosed/identified	Damage to medicine stocks	[86]
Taipei Hospital	Taiwan	13th August 2018	Not disclosed/identified	9 Deaths, 16 injured	[87], [88]
MINSK Belarusian Mental Hospital	Belarus	12th October 2003	Arson	30 Deaths, 31 injured	[89], [90]
Cavell Centre	England	August 2016	Attempted suicide by burning	1 Death	[91]
Berkshire Healthcare NHS Foundation Trust	England	6th December 2015	Arson	1 Death	[92]
Royal Marsden Hospital	England	2nd January 2018	Not disclosed/identified	Damage of property worth USD 858 million	[63], [93]
Royal Liverpool University Hospital	England	7th July 2015	Electric fire	Patients were evacuated	[94]
Broadgreen Hospital	England	1st January 2008	Not disclosed/identified	1 Death, 4 treated for smoke inhalation	[95], [96]
University College London Hospital	England	25th July 2008	Not disclosed/identified	Damage to underground structures	[63]
Great Ormond Street Hospital	England	29th September 2008	Not disclosed/identified	Damage of property worth USD 1.7 billion	[97]
Chase Farm Hospital	England	15th October 2008	Not disclosed/identified	Damage of property worth USD 103 million	[98]
Chase Farm Hospital	England	10th June 2018	Not disclosed/identified	7 Treated for smoke inhalation	[99]
Northwick Park Hospital	England	11th February 2009	Electric fire	Damage to sections of the building, implication on the heating, electrical and water supply systems	[63]
East Ham Memorial Hospital	England	2nd January 2002	Not disclosed/identified	Damage to ward	[100]

Warrington General Hospital	England	30th June 2005	Electric fire	Damage to underground power cables	[101]
Ramenskyon Psychiatric Hospital	Russia	26th April 2013	Smoking	38 Deaths	[62], [102]
Novogorod Psychiatric Hospital	Russia	13th September 2013	Smoking	37 Deaths	[103]
PRIMORSK, Leningrad Oblast	Russia	1999	Not disclosed/identified	21 Deaths	[104]
Drug Treatment Hospital Moscow	Russia	9th December 2006	Unsafe exposure of flammable material to high heat	45 Deaths	[105]
Baghdad Hospital	Iraq	24th January 2005	Electric fire	12 Infant deaths, over 100 injured	[106]
Jazan General Hospital	Saudi Arabia	24th December 2015	Electric fire	25 Deaths, 107 injured	[107], [108]
Calderon Guardia Hospital	Costa Rica	2005	Gas leak	18 Deaths	[109]
Southside Regional Medical Centre	USA	31st December 1994	Smoking	4 Deaths, 3 injured	[110]
St. Andrews Hospital	USA	31st October 2004	Electric fire	-	[111]
El Camino Hospital	USA	22nd February 2005	Electric fire	Damage worth up to USD 52,800	[112]
Rhea Medical Centre	USA	6th July 2006	Electric fire	Minimal damage	[113]
VA Hospital	USA	2004	Smoking	1 Death	[114]
Sheppard Pratt Hospital	USA	28th August 2003	Lightning	2 Injured	[115]
St John of God Hospital	Australia	1st November 2016	Kitchen fire	Patients were evacuated	[116]

* Monetary losses have been converted to equivalent USD value in March 2020

The sample-set consists of hospital fires that occurred in 17 countries. The distribution of the sample set country-wise is given below in Figure 18. The sample-set consists of hospital fires that occurred between the period of 1994 and 2019. The time distribution of the sample set can be seen in Figure 19.

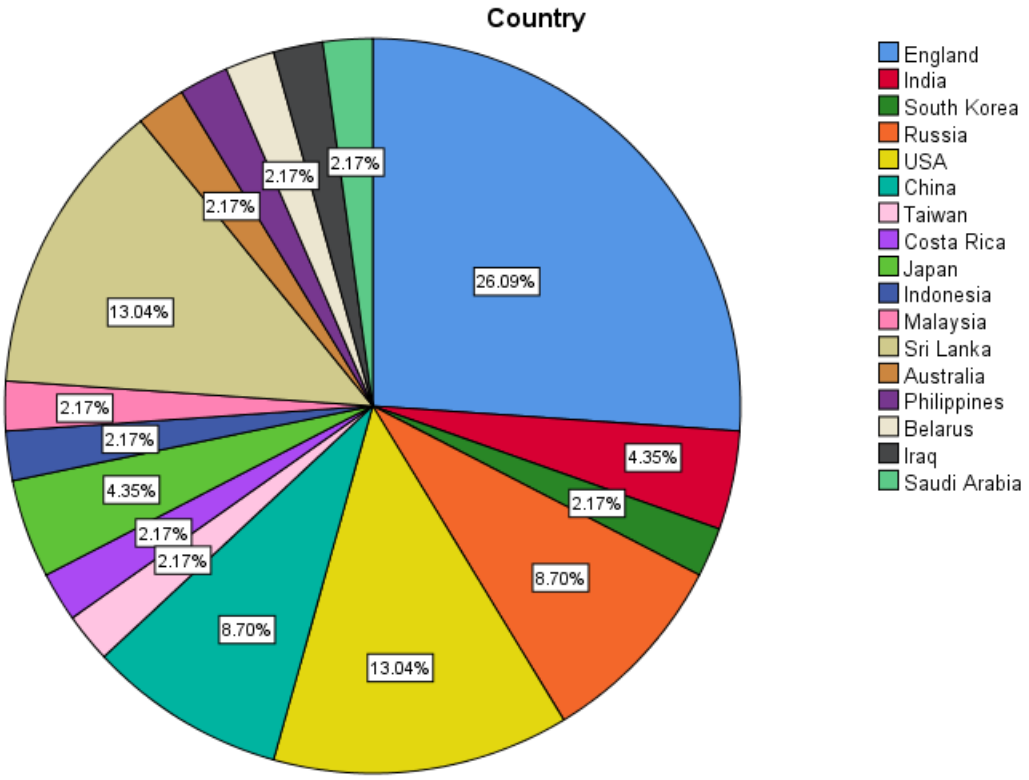

Figure 18: Countrywise distribution of the sample set

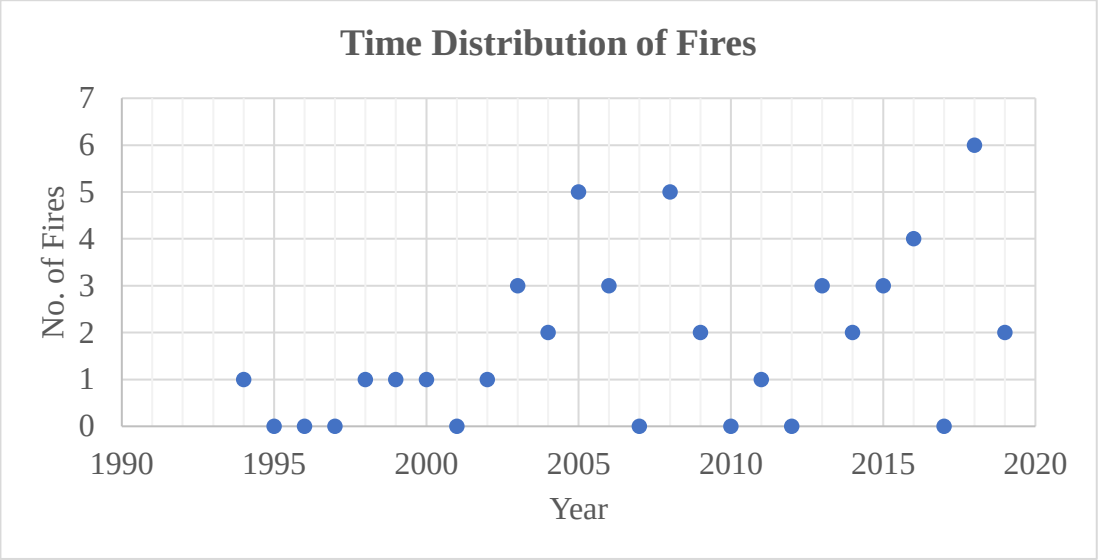

Figure 19: Time distribution of the sample set

A cross-tabulation of the causes of fire country wise is shown in Table 3.

In the sample set, a significant portion of the hospital fires did not have the cause of fire disclosed in the literature. In some other cases, the cause had not been identified. other than in those cases, the sample set revealed 11 causes of fire. They are as shown in Figure 20.

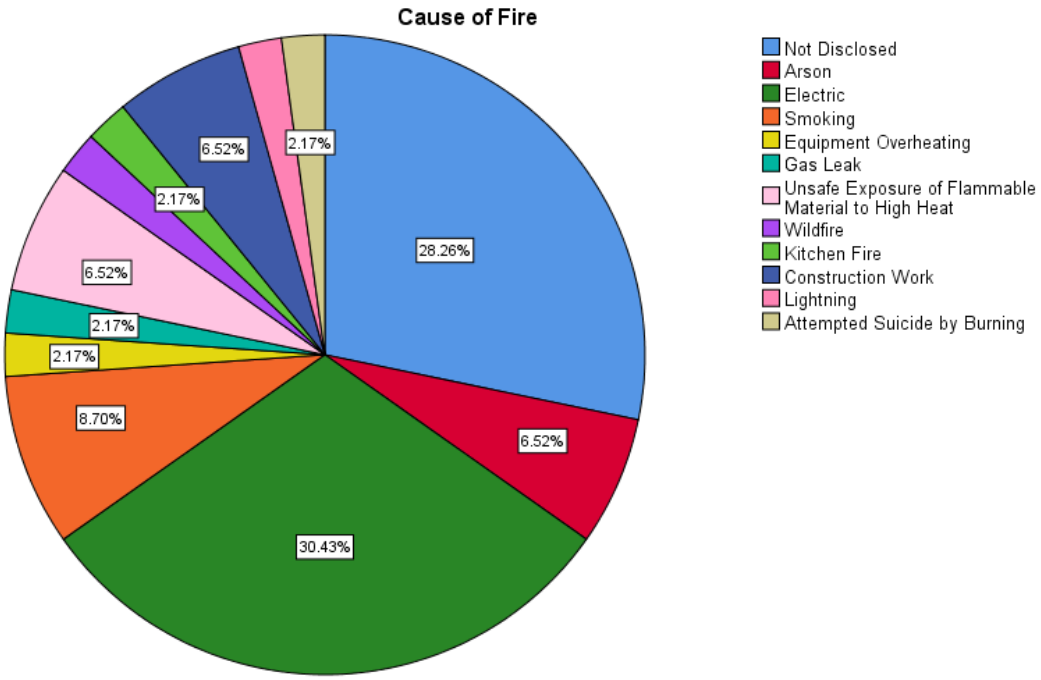

Figure 20: Distribution of cause of fire in sample set

Table 3: Tabulation of causes of fire countrywise

		Cause of Fire												Total
		Not Disclosed	Arson	Electric	Smoking	Equipment Overheating	Gas Leak	Unsafe Exposure of Flammable Material to High Heat	Wildfire	Kitchen Fire	Construction Work	Lightning	Attempted Suicide by Burning	
Country	England	7	1	3	0	0	0	0	0	0	0	0	1	12
	India	1	0	1	0	0	0	0	0	0	0	0	0	2
	South Korea	0	0	1	0	0	0	0	0	0	0	0	0	1
	Russia	1	0	0	2	0	0	1	0	0	0	0	0	4
	USA	0	0	3	2	0	0	0	0	0	0	1	0	6
	China	0	0	1	0	0	0	1	0	0	2	0	0	4
	Taiwan	1	0	0	0	0	0	0	0	0	0	0	0	1
	Costa Rica	0	0	0	0	0	1	0	0	0	0	0	0	1
	Japan	1	0	0	0	0	0	1	0	0	0	0	0	2
	Indonesia	0	0	1	0	0	0	0	0	0	0	0	0	1
	Malaysia	0	0	0	0	0	0	0	0	0	1	0	0	1
	Sri Lanka	2	1	1	0	1	0	0	1	0	0	0	0	6
	Australia	0	0	0	0	0	0	0	0	1	0	0	0	1
	Philippines	0	0	1	0	0	0	0	0	0	0	0	0	1
	Belarus	0	1	0	0	0	0	0	0	0	0	0	0	1
	Iraq	0	0	1	0	0	0	0	0	0	0	0	0	1
	Saudi Arabia	0	0	1	0	0	0	0	0	0	0	0	0	1
Total		13	3	14	4	1	1	3	1	1	3	1	1	46

This analysis shows that the highest cause of fires was electric fires at 30.4%. This was followed by smoking at 8.70%. However, it must be noted that the fires caused by smoking incidents occurred in the countries of Russia and the United States of America. The next greatest number of fire hazards were due to construction work done in hospitals, unsafe exposure of flammable material to high heat, and arson. It must be noted that this study looks at the causes of fires that gave major disastrous results and therefore the results will vary from a study looking at general causes of fires of all levels.

2.6.3 Past Studies of Fire Safety in Hospitals in Sri Lanka

In this section, a study was done on previous studies that were conducted to evaluate the fire safety performance of hospitals in Sri Lanka. This will give an idea about the current level of fire safety performance of hospitals in Sri Lanka.

A study was done by Gunathilaka in 2018 where he assessed the fire safety of three major tertiary hospitals in the country: District General Hospital Gampaha, Teaching Hospital Kalubowila, and Teaching Hospital Kegalle. The assessment was done across 12 different modules. These modules are given below [117].

1. Fire safety management
2. General fire safety
3. Electrical safety
4. Safety of heating and cooking appliances
5. Safety of building plants and machinery
6. Means of escape
7. Actions in the event of a fire
8. Fire detection and alarm systems
9. Portable firefighting equipment
10. Notices and fire safety signs
11. Fire safety facilities and liaison
12. Testing, maintenance, and records

The results of the fire safety performance assessment can be seen in Table 4. As can be seen, all three hospitals are in a low state, with the maximum value being only 53% for TH Kegalle.

Table 4: Results of fire safety performance by Gunathilaka (2018)

[117]

Hospital	Points	Percentage	Safety Index
Ideal Hospital	336	100.00%	1.00
Hospital in minimum acceptable fire safety level	250	74.40%	0.74
DGH Gampaha	140	41.66%	0.42
TH Kalubowila	130	38.69%	0.39
TH Kegalle	176	52.38%	0.52

A study was done by Kularatne (2018) where the fire safety systems of DGH Gampaha and TH Kegalle were assessed using a subsection of the Hospital Safety Index (HSI) system introduced by the World Health Organization and the Pan American Health Organization [118]. The results of the assessment are given below in Table 5.

Table 5: Assessment of fire protection systems using HSI guide

[119]

Check	Safety Level	
	DGH Gampaha	TH Kegalle
Condition and safety of the fire protection (passive) system	Low	High
Fire/smoke detection systems	Low	Average
Fire suppression systems (automatic and manual)	Low	Average
Water supply for fire suppression	Low	Low
Emergency maintenance and restoration of the fire protection system	Low	Low

Another study has been done by Munasinghe and Matsui (2019) in the DGH Matara regarding the overall disaster preparedness of the hospital [120]. This assessment has

included fire safety preparedness. The assessment revealed that the hospital, which is a major tertiary hospital in the Matara district had only 3 fire extinguishers and those were not regularly maintained. The hospital also lacked fire and smoke detection systems. It has been highlighted that the fire safety performance of the hospitals was one of the weakest areas of the hospital's disaster preparedness.

2.7 Disaster Risk Management

Disaster risk management is a complex process containing aspects such as the measure of individual and societal perception regarding disasters, objective assessment of disaster risk, development of preventative and mitigation measures, development of measures of response and recovery, and governance and financial protection and methods of risk transfer [121]. Disaster risk management can be of two ways: reactive and pro-active. The reactive approach is mostly concerned with crisis management and is less effective in disaster reduction. Therefore, a pro-active approach is most often recommended [122].

Disaster risk management has traditionally been a top-down administrative-centric approach. However, it is recommended that this approach should be changed into a more people-friendly horizontal or bottom-up approach. This will enable to empower disaster victims, thereby increasing their resilience. Strengthening the local capacities for disaster through stakeholder ownership can lead to a sustainable reduction in disaster risks with time [123]

It is important that disaster risk management of an institution is a multi-disciplinary approach, containing a balance of structural and nonstructural measures. Inclusion of disaster risk reduction legislation is an important element in this.

Disaster risk management is a process that should always evolve and improve. In any situation, one of the main goals in disaster risk management should be to raise the disaster services to international standards.

Disaster risk management provides a high benefit/cost ration, with relatively small investments leading to immediate and visible benefits during a disaster. Therefore, it should be highly encouraged for institutions, communities, and governments.

2.7.1 Introduction to Risk Management Processes

The risk management process consists of five main processes [124].

- Plan risk management
- Identify risks
- Perform risk analysis
- Plan risk responses
- Control risks

The combination of all these processes is needed for an institution to develop a good state of risk management.

Risks are of two types: known risks, that can be identified and analyzed and unknown risks, that cannot be priorly identified. A well-prepared institution should be aware of and ready to face both types of risks [125].

2.7.2 Plan Risk Management

This process defines the risk management activities that are needed. In short, it develops the risk management plan which contains the other 4 risk management processes: identification, analysis, planning responses, and controlling of risks.

Planning should be done after understanding and defining risk management in terms of the specified subject. This should include the risk attitudes of the stakeholders and the risk exposure of the environment. In developing the plan, the expertise of professionals in the subject area as well as stakeholders should be considered. The risk management plan should be developed considering the budget and schedule of the institution as well.

The risk management plan should include the components of methodology, roles, and responsibilities of risk management team members, budgeting, timing, categories of risk, definitions of risk probability and impact, reporting formats of the risk management processes, and tracking of risk activities [124].

2.7.3 Identifying Risks

The final goal of this process is to develop a risk register. Key personnel in this process should be administrative personnel as well as risk management team members. However, all personnel in the institution should be empowered to identify potential risks. This process is an iterative process, as new risks can develop with time. The developed risk register should be able to identify the frequency and impact of different risks.

Risks can be identified by reviewing past incidents, brainstorming, interviewing experts in the subject areas, interviewing experienced stakeholders, and conducting root cause analysis (Technique used to identify a problem, discover the underlying causes that lead to it, and develop preventative action) [124].

2.7.4 Perform Risk Analysis

Conducting a risk assessment helps an institution to evaluate its buildings and the activities conducted within in an organized way in order to evaluate areas of the system that could cause harm. Thereby, the institution can identify its weakness and decide on precautions that could be taken to lower the risk to an acceptable level [126].

The process of risk assessment should accomplish the following tasks [127],

1. Identify risks
2. Assign values to risks
3. Predict losses
4. Identify actions to reduce impact

The process of risk analysis includes the study of the probability of the occurrence of risks and their impacts on the institution. Thereby, the institution can prioritize the risks in order to plan a course of action. This will help to reduce the uncertainty related to the risks.

Risk analysis can be of two types: qualitative risk analysis and quantitative risk analysis. Qualitative risk analysis is usually a rapid and cost-effective method to plan risk responses. If required, it also lays the foundation for quantitative risk analysis. It is usually expected that qualitative risk analysis is performed regularly. Using the

process of quantitative risk analysis, the effect of the identified risks on the overall system/institution can be analyzed numerically. This produces quantitative information that can be used to support decision making to reduce uncertainty [124].

2.7.5 Plan Risk Responses

In this process, mechanisms are developed to counter the risks identified on the risk register. This process should include the identification of personnel to take responsibility for each risk response.

Figure 21: Process of planning risk responses

Risks can be countered in three different strategies: avoidance, transference, and mitigation. For risks with high impact, the strategies of avoidance and mitigation are recommended. The low impact risks, transference is accepted. Another strategy that could be used for such risks is acceptance [124].

Avoidance

This strategy involves the institution taking actions to either eliminate the threat or protect the institution form the impact of the threat. For example, installing automatic fire suppression systems in cooking ranges in the kitchen is a method of avoidance of fire risk.

Transference

This strategy involves the institution shifting the impact of the threat to a third-party. The shifting of the impact most often means the payment of a premium to the third-party who would take on the responsibility of the risk. This can include the use of insurance, performance bonds, warranties, and guarantees.

Mitigation

Mitigation is the strategy of raking actions to reduce the probability of occurrence or impact of a risk. This means reducing the probability of occurrence and/or impact to

an acceptable threshold. For example, installing sprinkler systems is a mitigation strategy in case of fire hazards, as the probability of fire spread can be minimized.

Acceptance

This final strategy is when the risk is identified, but it is decided not to take any action unless the risk occurs. This is done when other strategies are not possible or are not cost-effective. Acceptance can be passive or active. Passive acceptance relies on the institution dealing with the risk as it occurs. Active strategy is most often implementing a contingency reserve, which can include time, money, or resources in order to take care of the risk.

2.7.6 Control Risks

The process of risk controlling includes actions such as implementation of risk response plans, tracking identified risks, monitoring residual risks, identifying new risks, and evaluating risk process effectiveness. This process helps to improve the efficiency of the risk process to maximize the risk responses. Risk controlling can lead to choosing alternate strategies, carrying out a contingency plan, and implementing correcting action [124].

2.8 Frameworks, Regulations, and Codes

This section expands on different frameworks, regulations, and codes regarding the areas of disaster risk reduction, post-disaster management, and fire safety available for various countries and the world. Frameworks usually define priorities and approaches to achieving these priorities. Regulations are usually enforced by legislature and can vary from country to country. Unlike frameworks that can be optional, regulations need to be followed. Codes are guidelines to design and planning professionals to identify minimum requirements and plan accordingly.

2.8.1 Disaster Risk Reduction Frameworks

The Sendai Framework for Disaster Risk Reduction is the successor to the Hyogo Framework for Action 2005-2015. It is a voluntary and non-binding global agreement that plans out works for disaster risk management as well as maps out the course of the world until the year 2030. It was adopted by the United Nations member states in

March 2015. It's marked as the moment that the world fully moved its focus from Disaster Management to Disaster Risk Reduction (DRR) [128]. The Sendai Framework describes seven global targets.

1. Reduction of global mortality
2. Reduction of the number of people affected by disasters
3. Reduction of economic losses due to disasters
4. Reduction of damage to infrastructure and disruption of services
5. Increase of countries with disaster risk reduction strategies
6. Increase of international cooperation in developing countries
7. Increase of and access to early warning systems

The 4th target is especially important for this research, in terms of hospitals and other healthcare services.

Until recently, post-disaster management was the focal point when dealing with disasters. Consideration of pre-disaster preparedness or resilience was not taken into account on a large scale. Understanding that the lack of preparedness greatly reduces the resilience of a community to face disasters has shifted the world's point of view to the concept of DRR. This focuses on the complete life cycle of a disaster, which includes the stages of pre-disaster, disaster, and post-disaster [129].

2.8.2 Disaster Risk Reduction for Hospitals

In accordance with this need for disaster risk reduction, hospitals around the world have begun programs to make hospitals safe through activities such as risk assessments, disaster training of hospital staff and disaster and emergency management [23], [130]. These programs cannot be one-time things as disasters can repeatedly occur. Therefore, disaster risk reduction cannot be a linear process. Instead, it is a cyclic process consisting of five phases: prevention, preparedness, response, mitigation, and recovery [131].

For an institution like a healthcare system, disaster risk reduction and safety must be considered in many aspects. These aspects should generally consist of 3 major modules: safety of structural elements, safety of other non-structural elements, and emergency and disaster management in the hospital. Determining structural safety can

mean looking at how the structure has been affected by previous incidents and also the current building integrity. Non-structural elements include architectural elements, infrastructure and access elements, critical infrastructure and equipment, and supplies of the hospital. Disaster and emergency management can mean management activities such as emergency planning, coordination, and preparedness. In order to maintain a hospital at an optimum resilience level, it is important that all aspects are looked at and maintained [23].

The Safe Hospital Project is a collaborative effort between the University of Moratuwa and the Disaster Preparedness and Response Division, Ministry of Health, Sri Lanka, and was initiated in order to improve the disaster preparedness of hospitals in the country. The project looks at all aspects of disaster risk reduction in hospitals such as structural safety, nonstructural elements' safety, and emergency and disaster preparedness in case of events of natural hazards, man-made hazards, and biological hazards. Previous studies done in the project include an investigative study conducted in three tertiary level hospitals in the country regarding overall safety, looking at structural safety, nonstructural safety and emergency and disaster management, a questionnaire survey study regarding disaster preparedness of government hospital staff members, a study into the adaptation of the Hospital Safety Index Guide developed by the World Health Organization and the Pan-American Health Organization to suit Sri Lankan hospitals and the development of a hazard map for government-owned hospitals in the country [10], [12], [118], [119], [130], [132], [133]. Another recent study was the development of a Rapid Visual System (RVS) to assess the structural safety of hospital buildings in Sri Lanka against tsunamis [51], [134].

2.8.3 Building Regulations and Codes related to Fire Safety

Many countries now have building regulations and codes that ensure fire safety and performance in buildings. For this section, the following literature was reviewed: NFPA 1 Fire Code Handbook [135], The BS 9999 Handbook [136], National Building Code of India – Part 4 Life and Fire Safety [137] National Disaster Management Guidelines – Hospital Safety (India) [52], IFC Life and Fire Safety: Hospitals [138], and Firecode – fire safety in the NHS [139]. Fire Regulations (Sri Lanka) [140] and

Specifications for fire detection, protection, and suppression systems (Sri Lanka) [141] developed by the Construction Industry Development Authority (CIDA) were also reviewed.

2.8.3.1 Fire Safety Actions

According to these regulations, it can be seen that fire safety precautions should contain 4 major components.

1. Fire prevention
2. Fire detection and protection systems
3. Means of escape
4. Facilities for fire fighting

These components can again be categorized according to the time they need to be done, during the design and construction of the building, and during operation of the institution.

Fire prevention activities are very important as this allows the likelihood of the fire hazard occurring to be minimized. For example, the kitchen of a building has a high risk of fire. Installing automatic fire suppression systems in the cooking range of the kitchen is a good method of fire prevention. By analyzing the aspects of an institution that have a high risk of fire, the institution can take preventative action to minimize the likelihood of fire.

The risk and impact of fires in buildings are much lower currently than it was in the past due to the development of technology involved in fire safety. Installation of automatic fire detection and alarm systems, as well as sprinkler systems, will help to stop the fire in its initial stage. Similarly, other active fire protection systems such as fire extinguishers and fire hose reels are required in buildings. It is proposed that these systems are regularly maintained by the service staff of the institution and serviced by the installation company or other contracted company. For large institutions such as hospitals, it is recommended to have an incident command center that is operated 24/7 and there is a person in charge of fire safety at the institution.

The most important thing during a fire is to protect human lives, especially the people who are more vulnerable during a hazard, such as women, children, and the elderly.

During a fire, it is recommended to avoid using elevators. A multi-story building is required to have at least 2 exit ways. The stairways are required to be entered through a smoke-stop lobby. Also, the stairways should be pressurized, and emergency lighting should be provided. Each floor of the building should have evacuation maps and exit signs marked. Assembly points should be designated for the building and denoted by a sign.

Firefighting by the fire service department will be needed if a fire is not extinguished in its initial stages. In case of a fire, the fire service department needs to be contacted as soon as possible. In many developed countries, the automatic fire alarm systems are directly connected to the local fire service department, which means the response will be fast. When the fire brigade arrives at the fire, it is necessary that the fire brigade vehicles can access the building with the fire. This means the access to the building should be wide enough for the fire brigade vehicles.

2.8.3.2 Incentives to Follow Fire Safety Regulations

In many developed countries like the United Kingdom, following the building regulations relating to fire safety offers benefits so that there could be cost savings in terms of construction or more money could be gained (during selling or renting) by maximizing the use of space [142]. However, there are times that the fire engineering solutions in the building regulations will restrict architects and other building services [142].

Another incentive to follow safety regulations such as installing sprinkler systems and other fire protection systems is the reduction in fire insurance premiums of buildings [30]. This is a major factor owners consider in selecting fire protection systems for the buildings.

The biggest incentive to practice fire safety regulations is when those regulations are backed by the legislature. When there is legislature regarding following regulations in a country, it makes construction industry professionals and building and institution administrators more careful as not doing so could bring legal issues. This can be seen in many developed countries such as the United Kingdom.

For example, the Disability Discrimination Act 1995 in the UK promotes employers to ensure that all employees including with disabilities can evacuate the premises safely in case of fire [126].

In Sri Lanka, CIDA, previously known as the Institute of Construction Training and Development (ICTAD) introduced national fire regulations in 1997, following both the regulations of the British Standards Institute and National Fire Protection Agency of the USA. These regulations are followed by building contractors in the country. These regulations are not however enforced by legislature in the country. For new buildings such as commercial properties and high rises, the building designs are required to be passed through the National Fire Service Department to confirm that the designs follow the national fire regulations. However, the country does not have any regulations regarding updating old buildings to the current fire safety standards. This is commonly seen in old government-owned buildings such as government-owned hospitals.

2.8.4 Post-Disaster Management Frameworks

A disaster is most often a sudden and unforeseen event, which overwhelms local capacity and requires external assistance. These events can cause significant damage, destruction, and human suffering [143]. Administrators often find that working to recover from a disaster can be a challenge, as there is much greater pressure on them than during a non-disaster period. This is due to factors such as the need for rapid reaction and quick results, media attention, and the involvement of external stakeholders such as local and international aid agencies. This pressure can be increased when there is also a lack of experience and capacity in handling the work amount necessary [131]. Complete recovery from the disaster will include the restoration of not only the physical structures but also the social stability of the affected community. Recovery after a disaster includes a large range of activities and these work for recovery and coordination can be categorized into the following modules; Institutional arrangements for recovery, Post-disaster needs assessment, Recovery planning, Managing recovery, Building Back Better, and managing residual risks and Resource mobilization [131].

It is understandable that the method of disaster recovery can vary considering the factors relevant to each disaster, such as the type of disaster, its impacted population, and the significance of the damage on persons and properties. The guide to developing disaster recovery frameworks published by the GFDRR has its own separate modules that can be customized to suit the needs of the target audience. These six modules can be named as follows: Conducting post-disaster damage and needs assessment, Policy, and strategy-setting for recovery, Institutional framework for recovery, Financing for recovery, Implementation arrangements and recovery management, and Strengthening recovery systems in governance [143].

The recovery plan which would be successful in the long term would be a plan where the divisions of Finance, Regulation, and Administration work cohesively and concurrently so that all financial, technical, and human resources available can be used for recovery, reconstruction and risk management.

It is evident from historical incidents that disasters affect poverty-stricken families much more harshly, effectively paralyzing the production and income of families. In such a case, it is important that low-income victims of disasters are compensated fairly, considering both their injuries and losses as well as their predictable future losses due to the disaster. A major requirement here is ensuring the victims' job stability [144].

Vulnerability to disasters increases due to the weak environment and weak disaster management [145]. In order to build back better, it is important to not just restore the status of the institution to the pre-disaster state but to improve further. An institution's disaster management plan should not be allowed to stagnate but should be constantly improved, by taking lessons from past disasters [23].

According to the Disaster Preparedness and Response Division, Ministry of Health of Sri Lanka, there are several key indicators of the recovery plans of the health sector [145]. They are as follows.

a. The hospital being repaired and functional to their full capacities
b. Reconstruction of hospital structures incorporating disaster resilient features and following the Safe Hospital guideline given by the WHO and PAHO
c. Preparedness of healthcare systems to respond to disasters

d. Having conducted disaster drills
e. Number of households being covered under health insurance schemes

Post-disaster recovery planning means the development of a number of strategies to bring back the community or institution to where it was before the disaster and continue further to improve its state. These strategies can include the development and implementation of the following [146].

a. Post-disaster recovery plan
b. Recovery ordinances
c. Continuity plan
d. Post-disaster buildable lands inventories
e. Utility recovery and reconstruction plans
f. Temporary shelter plan
g. Establishment of a coordinating organization and guiding principles for reconstruction

There have been defined Standard Operating Procedures (SOPs) for hospitals themselves regarding emergency and disaster management. It can be seen in these guidelines, that hospitals must be concerned with external disasters occurring outside the hospital in the community as well as disasters that may occur within the hospital [147], [148]. The guidelines themselves are mostly concerned with the preparedness for disasters in hospital and are less descriptive regarding the recovery stage and the activities to be done. However, post-disaster follow-up and critique of actions during disasters have been mentioned to be a critical path of disaster management in hospitals [149]. This includes event analysis and incident reporting [138]. There are three main goals regarding protection from fire in hospitals; safety of life, protection of property, and continuous operation of the facility [138]. Disaster management in hospitals, which are institutions with already complex work, becomes even more complex [150]. Therefore, the actions taken must be careful, thorough, and well-planned.

2.9 Cycle of Fire Safety

Five major areas related to safety from fire hazards have been identified as shown in Figure 22. This includes fire prevention, fire mitigation, fire escaping, firefighting, and recovery.

The purpose of this study is to create a comprehensive fire risk management framework that is multi-dimensional. This means looking at the management of risk at all stages of the disaster cycle, including pre-disaster phase, disaster phase and post-disaster phase.

The pre-disaster stage is mainly about fire prevention. This means identifying the main causes of fire in an institution or a building and then taking the necessary steps to reduce the chance of the fire occurring.

Figure 22: Cycle of fire safety

The disaster stage means three kinds of aspects. The first aspect is fire mitigation. This can be achieved partly by detecting the fire at an early stage. Fire detection and alarm systems will be useful in this. The other part of fire mitigation is having passive and active fire suppression systems that can prevent further spread of fire and extinguish the fire. The second aspect is fire escaping. Here, both the building aspects and human aspects of the people inside the building need to be considered. The third aspect is

firefighting, which is the involvement of professionals from fire service departments in extinguishing the fire.

In short, in order to control the start and spread of a fire, actions must be taken to [57],

1. Reduce the frequency of fire hazards (Prevention)
2. Minimize the damage in case of a fire (Protection)

The post-disaster stage is about recovery and Building Back Better. This means looking at all aspects of the institution including the people, buildings and critical infrastructure systems, equipment and materials, and administrative and managerial work.

2.10 Fire Safety Components

Developing risk responses is an important part of risk management. This section explains about common risk responses in terms of fire safety. The fire safety components mentioned below are recommended to minimize the damage of a fire to both people and property. These risk responses include technical and human responses. The technical responses relate to actions such as fire mitigation through sprinklers and fire extinguishers, warning of fire hazards through alarm systems, and prevention of fire spreading through building elements such as fire doors and fire/smoke-stop lobbies. The human responses relate to actions such as protection from fire through firefighting and safety evacuation.

2.10.1 Fire Safety Systems

Fire safety systems have been introduced to building regulations in most countries and these regulations are enforced by the legislature in many developed countries. Prevention activities such as the installation of smoke alarms in high-income countries have proved to reduce fire rates in those countries [151].

The fire safety systems that are used in buildings are required by CIDA regulations to be compliant with NFPA and BSI regulations. To ensure compliance, it is globally required that the equipment be approved and listed by an independent third-party organization. The third-party organizations accepted by the CIDA are given below [141].

- Underwriters Laboratories (UL)
- Underwriters Laboratories Canada (ULC)
- Loss Prevention Council Board (LPCB)
- Factory Mutual (FM)

2.10.1.1 Fire Detection and Alarm Systems

This system is the combination of devices such as smoke/heat detectors, manual call points, and sounders which will make sound or light up an alarm, if the detector detects smoke or heat or if a person operates a manual call point. The objective of automatic fire alarm systems is to prevent or minimize losses caused by fire, which could be life or property [142].

Fire detection and alarm systems detect fire by monitoring environmental changes associated with combustion. The quick detection allows time to take action to evacuate the occupants in the building and to control the spread of fire. The most reputed standards for fire detection and alarm systems designing are BS 5839 and NFPA 72 [150], [151], [152]. According to BS 5839, there are 3 categories of fire detection and alarm systems.

1. Category M – Only manual alarm systems, no automatic fire detectors
2. Category L – Automatic detection systems intended for the protection of life
3. Category P – Automatic detection systems intended for the protection of property.

Fire Alarm Control Panel

A Fire Alarm Control Panel (FACP) must be located at a designated fire command center on the ground floor or other suitable location. The FACP is the coordination point of the fire detection and alarm systems as it monitors the inputs and the outputs of the systems. During a fire, the FACP should be able to identify the location of the fire through zoning of the systems.

Fire Detectors

There are several types of fire detectors that can be used.

1. Smoke detectors

This type of detector responds to particulate products of combustion. The coverage area of a smoke detector is about 100 m^2. Smoke detectors can be of two types: photoelectric and ionization detectors. CIDA guidelines do not allow for ionization type to be used.

2. Heat detectors

This type of detector responds to an increase in temperature. This type of detector is used in areas such as kitchens and garages where smoke is often encountered. The coverage area of a heat detector is approximately 50 m^2. Heat detectors are of two types: fixed temperature detectors, which react when the temperature reaches a specified point, and rate-of-rise heat detectors, which react to a sudden change in temperature (Rate = 8 ºC per minute).

3. Other types of detectors

Other types of detectors include multi-sensor using combined techniques, flame detectors (infrared and ultraviolet), and video smoke detection.

Manual Call Points

This is a device requiring manual activation of the fire alarm system. They are required to be installed along escape routes, at 1.4 m above floor level, and located so that a person can reach a point in less than 30 m. There are two types of these devices: single-action call point and double-action call point. Single action call points require a single action to activate the signal (E.g. Press a button, break the glass). Double action call points require two actions to activate a signal (E.g. Push and pull down).

Warning and Alarming Devices

Fire alarms can be of two types: audible and visual. To attain a better risk response, CIDA recommends installing both types of alarms.

Audible alarm: This can be done through alarm bells of electronic sounders. The output should generate a sound output of at least 10 dB above the ambient noise level.

Visual alarm: This type of device is named as strobes. They emit a beacon type flashing light and are recommended in areas such as hospitals where audible alarms cannot be used as the initial alarm.

The components of a fire detection and alarm system can be seen below in Figure 23, Figure 24, Figure 25, and Figure 26 (stock photos).

Figure 23: Manual call point

Figure 25: Heat detector

Figure 24: Smoke detector

Figure 26: Fire alarm sounder

2.10.1.2 Sprinkler Systems

The presence of sprinklers in a building greatly reduces the probability of the fire spreading beyond the material of fire origin from 0.680 to 0.181 (Statistics for a storage room). Similarly, the probability of the fire spreading beyond the room of fire origin is reduced from 0.2000 to 0 with the installation of sprinklers [57]. It has been revealed that 70% to 90% reduction to damage could be made in terms of costs through the installment of sprinklers [155].

Sprinkler systems are required to be installed in indoor car parks, high-rise, and super high-rise buildings, basements, and industrial buildings. The functions of a sprinkler include detection of fire, raising the alarm, extinguishing the fire, and preventing the spread of fire.

The most reputed codes for design of sprinkler systems are BS EN 12845:2015 and NFPA 13 [154], [155]. The design of sprinkler systems varies with the hazard class of the building. The three hazard classes are as follows.

1. Light Hazard (LH) – Occupancies with low fire loads and low combustibility
2. Ordinary Hazard (OH) – Occupancies where combustible materials with a medium fire load and medium combustibility are processed or manufactured
3. High Hazard (HH) – Occupancies with materials that have a high fire load and high combustibility and can develop a quickly spreading or intensive fire

Sprinkler Head

The main types of sprinkler heads are fusible solder type and liquid bulb type.

A fusible solder type sprinkler head consists of two metal elements connected by a heat-sensitive alloy. This link holds the plug in place. When the heat reaches a certain temperature, the link releases, causing the two metal elements to separate. This causes the plug to fall and the water is released.

A liquid bulb type sprinkler head contains a glass bulb containing a liquid with a gas bubble. During a fire, the liquid expands with the increase of temperature, thereby compressing the gas bubble. At a certain temperature, this expansion causes the glass bulb to shatter and releases the water seal. In a way, the sprinkler system also acts as a fire detection system. A sprinkler head can be seen in Figure 27 (stock photo).

Figure 27: Sprinkler head

The maximum area per sprinkler head and maximum spacing between sprinkler heads according to the hazard class are given in Table 6.

Table 6: Maximum coverage area of and spacing between sprinkler heads

Hazard Class	Maximum Area per Sprinkler (m^2)	Maximum Spacing (m)
LH	21	4
OH	12	4
HH	9	3.7

Sprinkler Installation

There are several types of sprinkler installation: wet pipe system, dry pipe system, alternate system (wet and dry pipe), pre-action system, and re-cycling pre-action. The most commonly used system is wet pipe system. Dry pipe system is recommended for locations that experience winter seasons.

Water Storage

The water storage should have a sufficient supply so that the system can be equipped for a minimum of the durations given below.

- LH – 30 minutes
- OH – 60 minutes
- HH – 90 minutes

2.10.1.3 Fire Extinguishers

Fire extinguishers are the first line of defense during a fire and can be used to extinguish or control the fire in its initial stage. The fire extinguisher that needs to be used differs with the type of fuel of the fire. The most referred codes of practices for

portable fire extinguishers are BS EN 3 and NFPA 10 [158], [159]. Table 7 below shows how to choose the extinguisher considering the type of fire [158].

Table 7: Choosing fire extinguisher type

Extinguisher Type / Type of Fire	Water	Foam	Dry Powder	Carbon dioxide	Wet Chemical	Graphite Powder
A	✓	✓	✓	✓	✓	✓
B		✓	✓	✓		
C			✓			
D						✓
E			✓	✓		
F					✓	

2.10.1.4 Fire Hose Reel

Fire hose reels are usually located strategically in a building in order to provide a sufficient amount of water to extinguish a fire. a fire hose reel system will contain pumps, pipes, and a supply of water [160]. Figure 28 shows a typical water hose reel.

Figure 28: Water hose reel

The followed codes related to hose reel systems are BS EN 671-1 and NFPA 14 [161], [162]. According to regulations, fire hose reel assemblies should be provided next to the hose reel with operational instructions on display. The hose reels should be of the dimensions of 19 mm diameter and 30/45 m length or 25 mm diameter and 30 m

length. The water pressure at the nozzle should produce a throw of 6 m at 30 liters per minute rate. The nozzle control settings should be shut and spray and/or jet.

2.10.1.5 Fire Blanket

A fire blanket can be used to extinguish a small fire or to wrap around a person during a fire. The fire blanket is a highly flame-resistant blanket made from 2 layers of woven glass fiber fabric enclosing a layer of fire-retardant film. The fire blanket works by cutting off the fire's oxygen supply [163]. The blanket should be contained in white containers and mounted on the wall.

2.10.1.6 External Fire Hydrant

An external fire hydrant is used to provide a sufficient level of water supply with adequate pressure during a fire. This is often seen present in a building where the fire brigade vehicles cannot access the building [140]. The design of external fire hydrants should conform to BS EN 14384 [164].

An example of a fire hydrant can be seen in Figure 29 (stock photo).

Figure 29: External fire hydrant

2.10.2 Building Components for Fire Safety

2.10.2.1 Fire Door

CIDA regulations require that fire doors conform with BS 476 Part 22A [165]. Fire doors separate fire compartments and are usually fire retardant and shatterproof. Fire doors are required to have a fire-resistance in the range of 30 to 120 minutes. The construction material may be timber or metal, as specified in the project specifications.

There should be a vision panel made with fire resistance glass in the dimensions 300 mm x 200 mm. the door frame and door edge should have fire-rated seals. Finally, the doors should be self-closing. Figure 30 gives a diagram detailing a fire door and its various components.

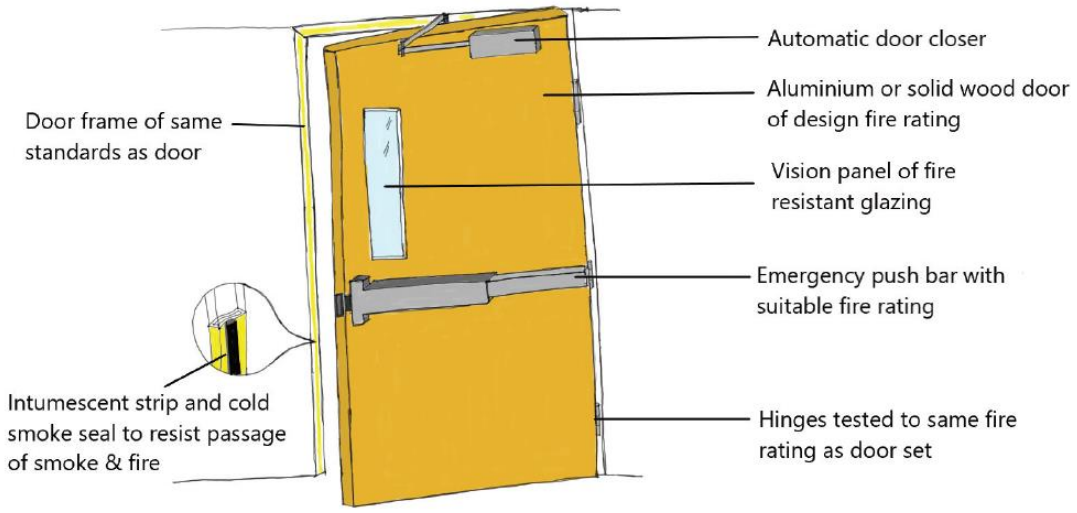

Figure 30: Diagram of a fire door

[167]

2.10.2.2 Fire/Smoke-Stop Lobby

This is a lobby located at the entrance of a staircase which will prevent or minimize the smoke entering the staircase. The smoke stop lobby should follow the BS 5588 codes [166]. The lobby must be separated from the adjoining areas by a wall with a fire rating according to specifications. The specifications depend on the purpose of the building. The access to the lobby should be equipped with a fire door. The lobby floor area should be more than 3 m^2. If the lobby is also designed to serve as a firefighting lobby, the minimum area should be 6 m^2. The lobby should be designed in a way that escape movements are not impeded.

An example of a smoke stop lobby is given in Figure 31.

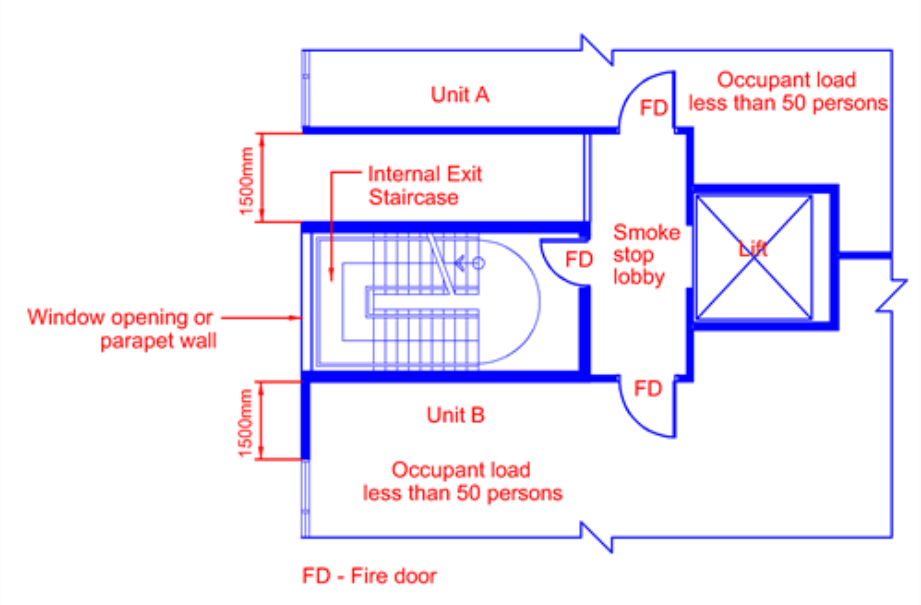

Figure 31: An example of a smoke-stop lobby

[168]

2.10.3 Fire Insurance

Fires can cause significant casualties and large losses, especially in places such as hospitals that have a high number of people who are not familiar with the surroundings. Rescue, medical air, and compensation needed for loss of life and other injuries can be costly and beyond the administration's ability to spend. This will cause instability in the community [169]. This is why insurance against fire hazards is so important, as it a form of risk transference.

2.10.4 Fire Safety Training

Providing fire safety training to staff of an institution as well as conducting regular fire drills is an important part of fire risk management. In a hospital, especially, the presence of nursing staff with fire safety training is the best defense in the face of a fire [59]. A study done in Malaysia regarding preparedness and resilience in hospitals has shown that human resources and training have been ranked highest in terms of preparedness and the ability to adapt in a timely manner has been ranked highest in terms of resilience [170].

There are instances that hospitals do not consider fire hazards as a top priority, especially in highly controlled areas such as operating theatres. However, surgical fires have been ranked as the number 3 among the top 10 technology hazards [171]. Many professionals mistakenly assume that if a fire occurred in an operating theatre, then that fire was not preventable. However, most surgical fires are preventable. Preparing for a fire hazard is important in a hospital, as there will be a large population of weak and vulnerable patients who will be depending on the staff members for their safety [172]

Fire hazards have the potential to occur suddenly and without warning. They can become intense quickly, and therefore the response to fire needs to be very quick in order to minimize the losses [173]. If staff members have not had previous training, it is not realistic to expect that they would effectively respond to a fire [174]. Although panic behavior is not common in the face of a fire, the lack of knowledge on the fire emergency actions as well as the induced stress can end up causing people to make fatal errors [175]. The lack of staff training in fire safety can increase confusion, which would increase the danger during the time of a fire hazard [176]. In some people, the lack of previous experience can cause the phenomenon of "cognitive paralysis", where people end up not taking any action. This can lead to fatalities that could have been avoided [177], [178].

Fire safety training has been identified as a tool to help improve fire safety knowledge and the response to a fire. This can result in minimizing fire-related casualties [179]–[181]. Fire safety is the collective responsibility of all staff members and therefore, it is important that staff members in each department of the hospital are actively involved in fire safety training [182]. The way a person acts during a fire depends on factors such as personality and leadership abilities, decision-making styles, and amount of fire training received [183]. Therefore, when assigning disaster and emergency duties to the staff members, the above-mentioned factors should be considered.

Fire safety drills should be used in institutions as they are effective in converting fire safety training into experience that the staff members can use to respond effectively during a fire hazard [184]. This experience helps a person to effectively analyze the situation and correctly understand the information in the surroundings [173]. Previous

studies have found that unannounced drills and exercises are often more effective [185].

An experiment done in the Netherlands shows the effectiveness of hospital staff training in evacuation. The same evacuation procedure was practiced in two rounds for patients of different medical status. It was observed that during the second round of evacuation, the hospital staff managed to achieve a significantly better evacuation rate [66]. The results of the experiment have been illustrated as seen in Figure 32.

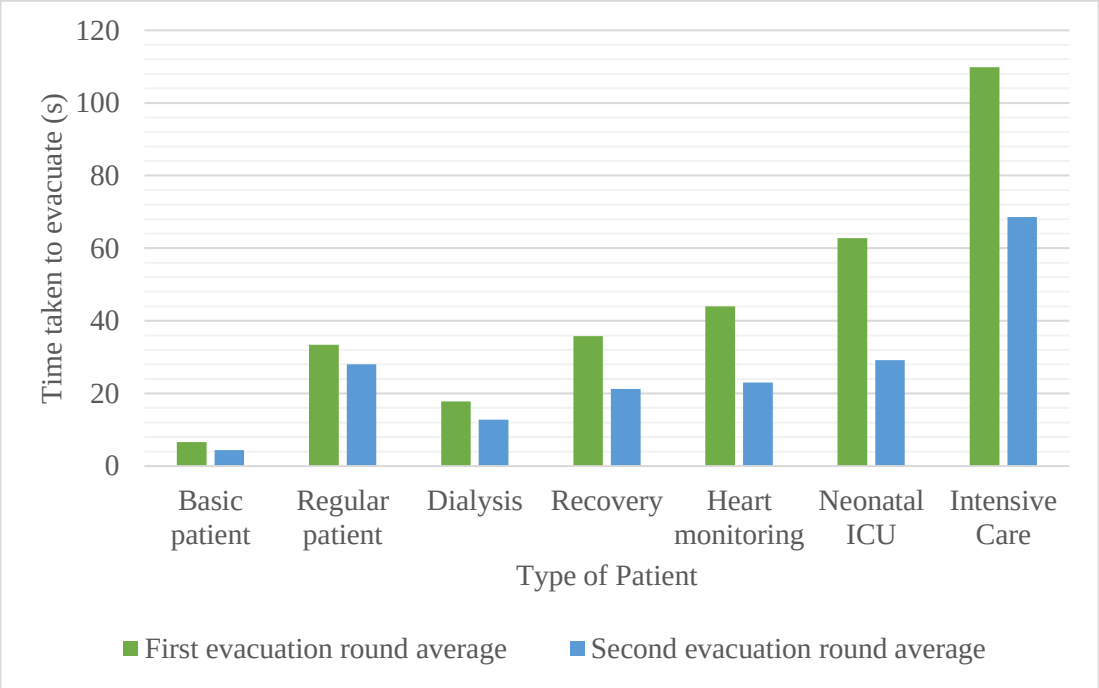

Figure 32: Influence of trained staff during evacuation

The training given to an institution's staff should be customized to the characteristics of the workplace. The training should [126],

- Provide information about the emergency procedures
- Consider the duties and responsibilities of the staff
- Be understood by the staff
- Consider the results of risk assessments done for the institution

Fire training should include providing the staff members with a sufficient level of the knowledge of operating and maintaining fire safety equipment such as fire extinguishers, fire hose reels and fire blankets [186], [187]. The training should also

include a description of staff duties, emergency evacuation procedures, and contacting the local fire service department [188]. It is important that the training is conducted so that the participants fully understand it and know their roles. Therefore the training should not only include a sufficient amount of time on life safety training and drills, it should also be of good quality and tailored to the participant group [189]. Fire safety training should also be conducted at regular periods of time, so that the staff members continuously review, revise, and reconfigure their knowledge on fire safety [190].

Fire safety preparedness should include developing and maintaining a fire safety plan. Two essential actions for fire safety in an institution is the appointment of a fire safety manager, who is responsible for the overall fire safety management, and the maintenance of a fire safety manual, which will contain all documentation regarding the fire safety planning in the institution [166].

2.10.5 Notices and Signs

Fire safety notices and signs are an important part of fire risk management, especially in buildings where a large portion of the people are unfamiliar about the premises, such as in hospitals. These signs can include instruction on fire safety equipment usage, notices on fire-action, signs for assembly areas, and emergency exit signs.

The fire safety signs should follow the guidelines of BS ISO 3864 Part 1 [191]. Exit and directional signs are required to be white on green backgrounds and should be illuminated at all times. Some examples (stock photos) can be seen in Figure 33 to Figure 36.

Figure 33: Fire action notice

Figure 34: Fire door notice

Figure 35: Emergency fire exit sign

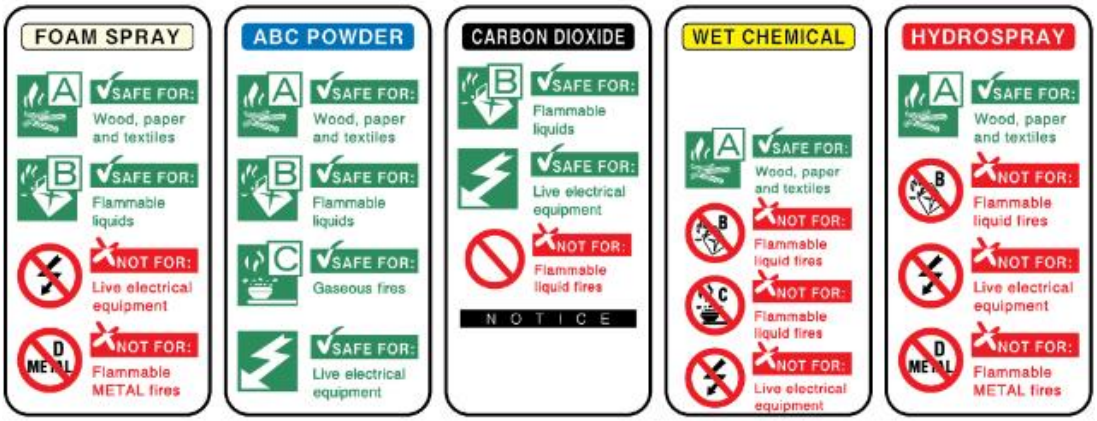

Figure 36: Fire extinguisher instruction notice

2.10.6 Economics of Fire Safety

Fire poses a risk, especially to the built environment. However, this risk can be reduced through careful management and building design [50]. Fire safety economics is about striking a balance between cost and safety. It is not possible to completely negate the probability of a fire in a building. Therefore, it is not advisable to completely focus on fire prevention. It is similarly inadvisable to only depend on recovery from a fire hazard, as this would leave the people and property in the building in a vulnerable state. A property owner or building administrative should take action to choose the best program that balances fire prevention, fire protection, and insurance as suited to the building and its functions [57].

2.11 Involvement of the Fire Service Department

2.11.1 Contribution from the Fire Service Department

The work done by the local fire service departments is an important aspect of fire safety management for any institution. Several studies have shown that the home fire and safety check (HFSC) conducted by the FRS is one of the best ways to reduce the damage due to fires [192]–[196]. The HFSC program in England which conducted over 1.9 million HFCS saw a decrease in the number of fatalities as well as a reduction of fatalities and injuries in fires that occurred [196]. Similarly HFSC programs in Australia and British Columbia, Canada experienced similar benefits from HFSC programs such as reduced number of fires and reduced severity of the fire that occurred [194], [197].

A study by Sund et al. (2019) has suggested that on-duty firefighters have reduced the number of fires by 6% between 2010 and 2015 in Sweden [151]. This reduction has saved SEK 10 million (Roughly USD 1 million) for 8795 households.

2.11.2 Fire Service Department in Sri Lanka

The Fire Service Department in Sri Lanka plays an equally important role in fire safety in the country. In addition to fire rescue services, the department performs various other services. In terms of fire prevention, the department is involved in updating the code of fire safety practices and fire precautionary requirements. The department also conducts fire safety inspections in high rise buildings and offensive trades, conducts public awareness programs in fire prevention, and conducts investigations of fire incidents. In terms of fire safety operation and training, the department conducts fire and evacuation drills in high rise buildings, fire, and rescue training programs for government and private sector staff, community awareness programs, and fire service familiarizing programs for school children. In 2018, the Colombo Municipal Council (CMC) Fire Service Department performed 342 fire calls, 35 rescue calls, 44 emergency calls, and 27 ambulance calls [198].

Sri Lanka has Fire Stations (FS) all over the country. The FS are affiliated with the district municipal councils. The various fire stations in Sri Lanka can be seen in Figure 38 and Figure 39.

The CMC fire service department has a main fire station, 4 substations, a station focused holding the fire prevention division, and a fire and rescue training academy. The main fire station has 5 separate divisions: administration, operation, training, transport, and communication. The hierarchy of the officials in the fire service department is given in

Figure 37. The main fire station is headed by the Chief Fire Officer while the substations and training academy are headed Divisional Fire Officers. The Fire Prevention Division is headed by the Assistant Chief Fire Officer. In the main fire station, the transport division is headed by a divisional fire officer, while the divisions of administration, operation, training, and communication are headed by station officers.

Figure 37: Hierarchy of officials in fire service department in Sri Lanka

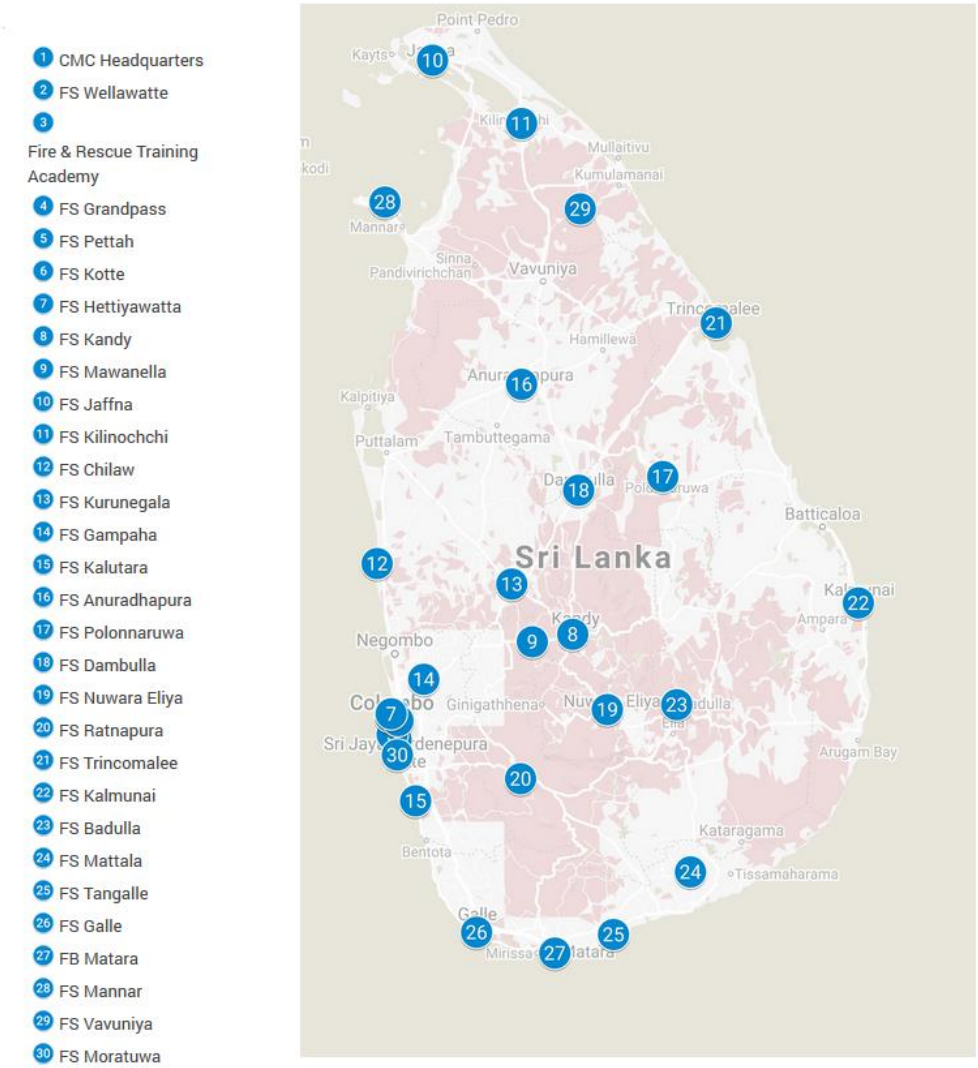

Figure 38: Fire stations in Sri Lanka

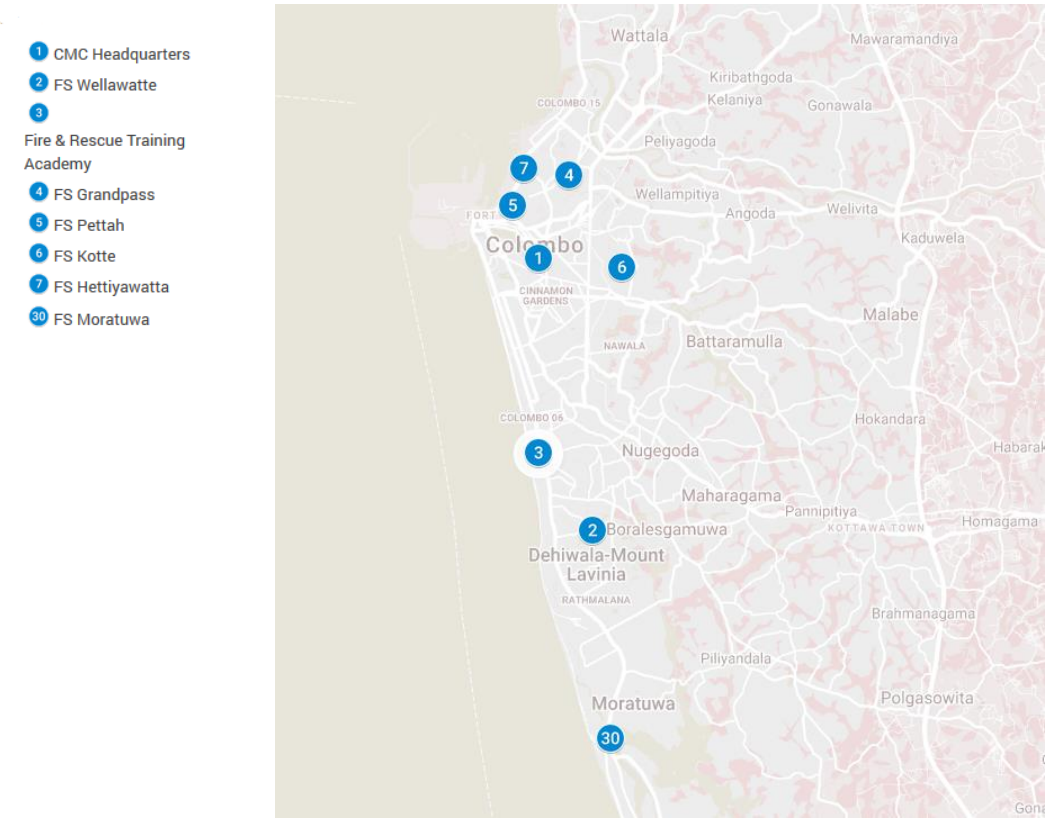

Figure 39: Fire stations in Colombo district

2.11.3 Travel from a Fire Service Department to the Location of a Fire

When a fire hazard occurs, each second the fire is left unattended, it continues to grow, causing damage to equipment and other valuables and increasing the danger on the humans and other living creatures on the property. Therefore, it is important that firefighting activities commence as soon as possible [199]. In regard to fire brigades during a fire, there are five types of time periods. The first is the dispatch time, which is the time taken to receive notification of the hazard and process the information. Next is the turnout time, which is the time taken to respond since acknowledging the emergency. The National Fire Protection Association (NFPA) of the United States of America recommends a turnout time of 1 minute [200]. Then comes the response time, which is the time taken to travel from the fire brigade to the hazard location. The NFPA recommends a time of 4 minutes for the first firefighting truck to arrive at the location [200]. Next is the access time, the time required for the firefighters to move from the firetruck stop to the hazard location. Finally is the setup time, which is the time taken for the firefighters to prepare to extinguish the fire [199].

3 Research Methodology

3.1 Introduction

This section describes the methodology followed in the research study. After the conduction of the literature review, a desk study containing regarding 3 topics was conducted. Next, a preliminary hospital survey was done in six governmental hospitals. Then, a tool to assess the risk management of fire in hospitals was developed and the applicability was tested in three major hospitals. A survey of hospital staff regarding the preparedness to face hospital fires was conducted. Finally, a list of post-disaster activities for a fire hazard in a hospital was developed.

3.2 Methodology Flow Chart

The methodology is described in Figure 40.

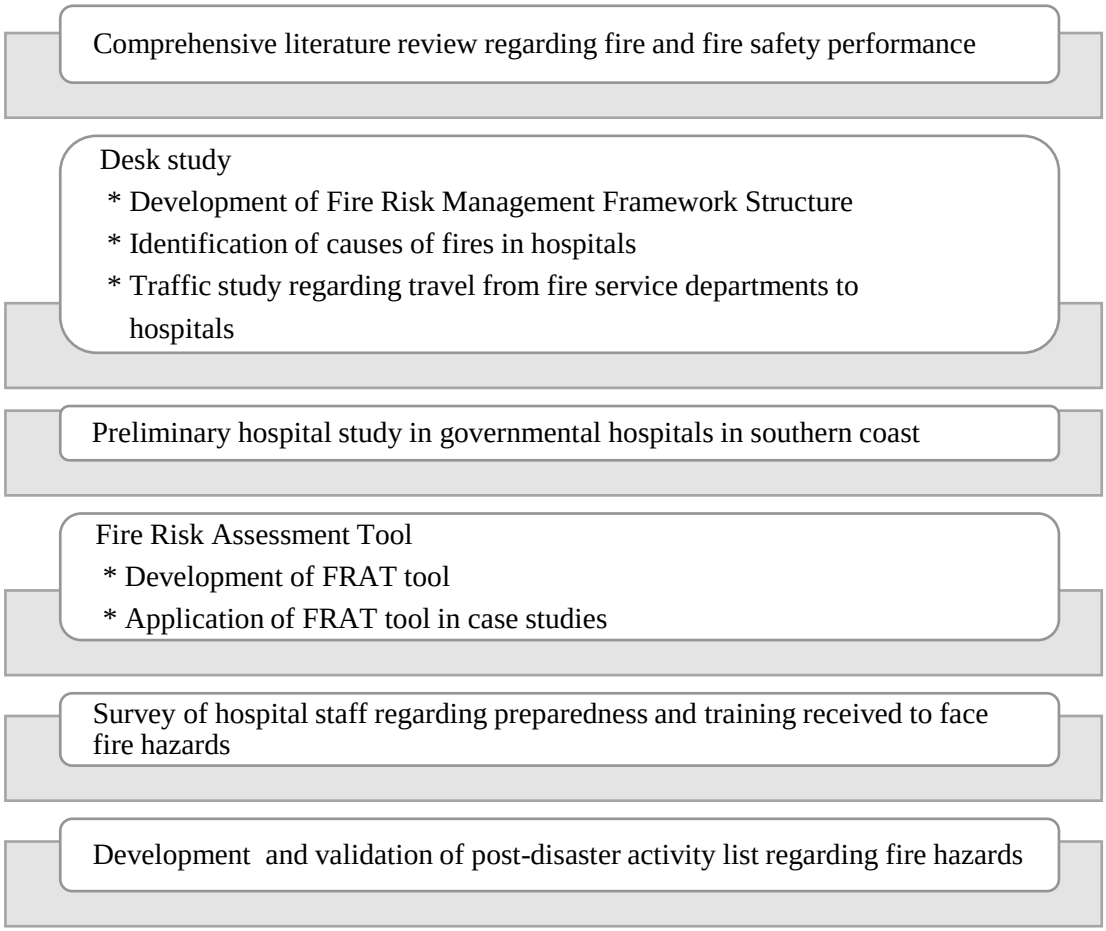

Figure 40: Research methodology flow chart

4 Development of Fire Risk Management Framework Structure

As identified in the literature review section, risk is a function of the hazard, exposure level of the community, and preparedness of the community to the hazard. In order to proceed with the study, first, these 3 elements had to be identified in terms of a fire hazard. The element of hazard was taken to define the class of fire hazard. This can be Light Hazard, Ordinary Hazard, or High Hazard class [140]. The second element, exposure, will be defined by the causes of fire in hospitals. The third and fourth elements are the preparedness and capacity of the hospital to face a fire hazard. This is where risk management enters the topic. This structure can be seen in Figure 41.

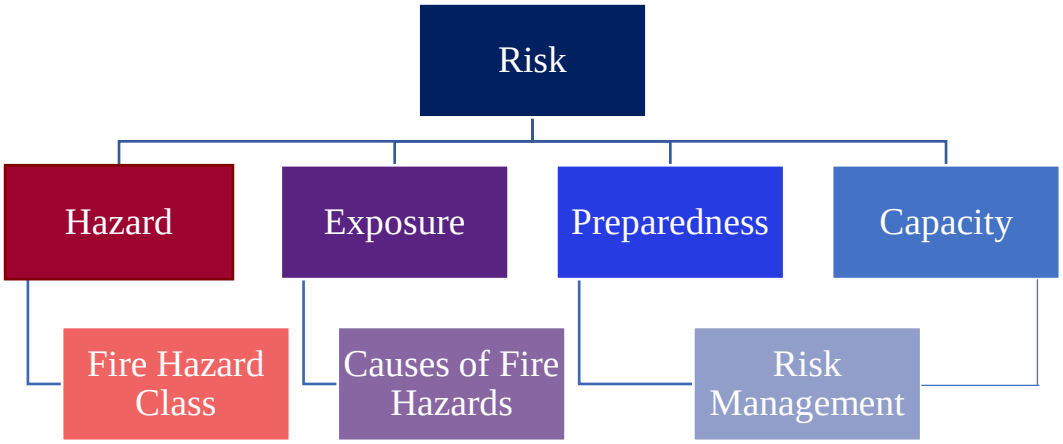

Figure 41: Structure of risk considering fire hazards

Fire risk management should be included from the beginning of a system and continuously maintained. Therefore, the developed FRMF structure has been separated into two major phases of a healthcare system: design and construction phase of the hospital buildings and operation and maintenance phase of the healthcare system.

Six sections have been identified in the design and construction phase. The first is the fire-resistant structures. For example, having the building constructed with materials of high fire-resistance such as concrete. Next, is passive fire suppression systems that should be included in the design of the buildings such as fire/smoke dampers and fire doors/walls. Then there are active fire suppression systems that should be installed during the construction of the building including sprinkler systems, fire hose reels, landing valves, risers, and fire pumps. Fire detection and alarm systems are also needed for fire safety in a building. Means of escape during a fire or other emergency are also

required to be considered during the design and construction of a building. The elements in a building facilitating emergency escape such as corridors and staircases should be constructed in such a way that a majority of the population in the building can be evacuated safely and in the quickest way possible. The final section in this phase is the inclusion of building amenities for firefighting such as fire lifts, two-way communication systems, and access points for fire brigade vehicles.

The second phase of the FRMF is operation and maintenance, which can be divided into 2 sections: system installation, maintenance and inspection, and fire safety management.

The section of system installation, maintenance, and inspection has two subsections. The first subsection, systems installation looks at active fire suppression systems that need to be provided to the building such as fire extinguishers. The subsection of maintenance and inspection is regarding the maintenance and inspection of hazardous locations and systems in the hospital, fire detection and alarm systems, and fire suppression systems.

The section of fire safety management is divided into three sections. The first subsection of planning and management should look at all stages of disasters in developing a fire safety plan, assigning staff responsibilities in a hazard and risk transference through insurance. The second subsection is training and drills for staff in case of a fire, which would include training for basic firefighting and emergency evacuation. The third subsection firefighting services look at services provided by the local fire service department. The subsection looks at travel and access routed to the hospital from the fire service department, services provided by the department in terms of fire safety training, and communication between the hospital and the department.

This complete structure of the FRMF developed can be seen in Figure 42.

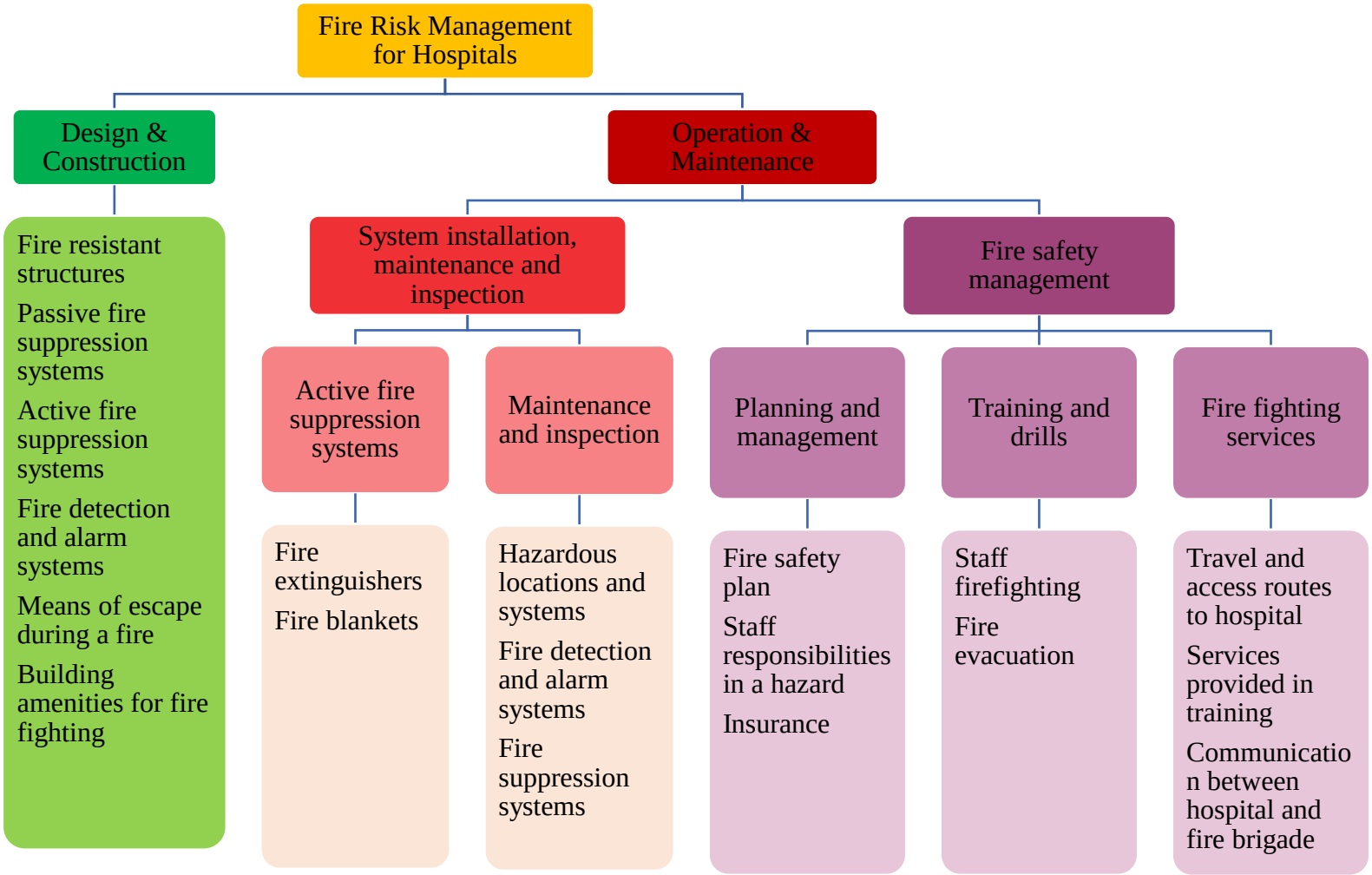

Figure 42: FRMF Structure

5 Study of Travel from Fire Brigades to Hospitals

5.1 Introduction

The inclusion of fire service departments in the community is an important factor in fire risk management of institutions like hospitals. As a fire begins to spread from its point of origin and grows, it becomes difficult and too risky for the institution's staff to suppress by themselves. The best course of action for personnel in the building will be to evacuate as soon as possible. At this point of the hazard, firefighting professionals will be needed.

As mentioned previously in the Literature Review, a recent study by Gunathilake (2018) in the hospitals of District General Hospital (DGH) Gampaha, Teaching Hospital (TH) Kalubowila, and TH Kegalle yielded results showcasing poor fire performance in all three of the hospitals [117]. One way of compensating for this poor performance is having a good fire service at a suitable traveling distance to the hospital. This part of the research study was done to investigate if this was the situation for these hospitals.

5.2 Methodology

An initial study was done to predict the response time of the fire service departments with regards to these three hospitals as well as the National Hospital (NH) of Sri Lanka. For this, travel time was collected through Google Maps [201]–[204]. The time taken for travel was observed at one-hour gaps for 24 hours starting from Monday 10:00 a.m. to Tuesday 9:00 a.m. on a non-holiday week. The maps and the paths monitored can be seen in Figure 43 to Figure 46.

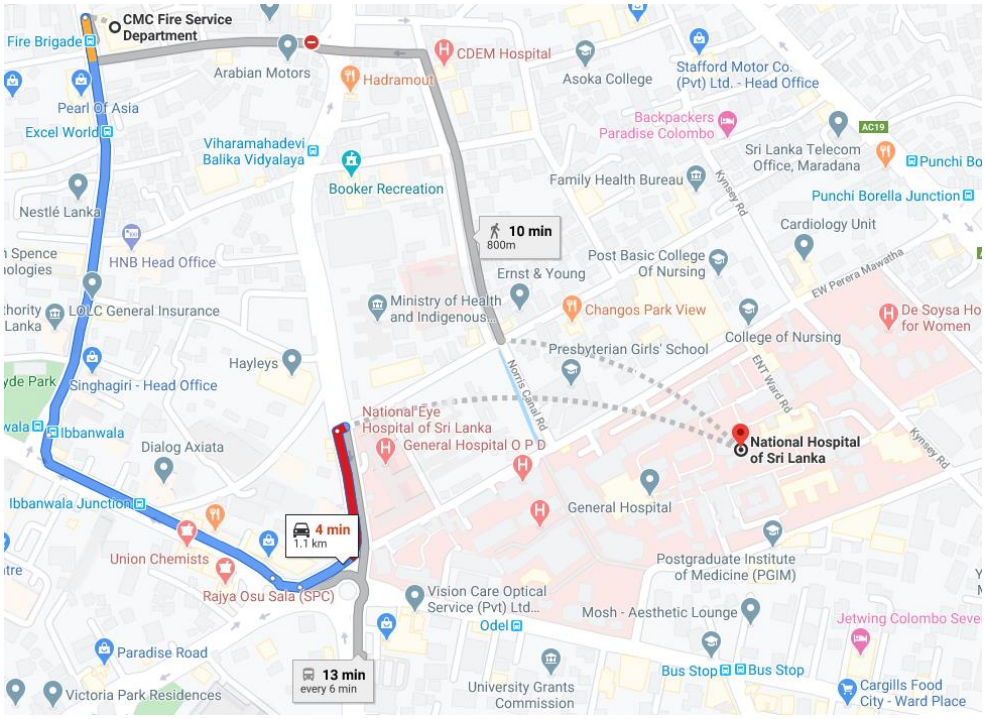

Figure 43: Path of Colombo Fire Service Department to NH Sri Lanka

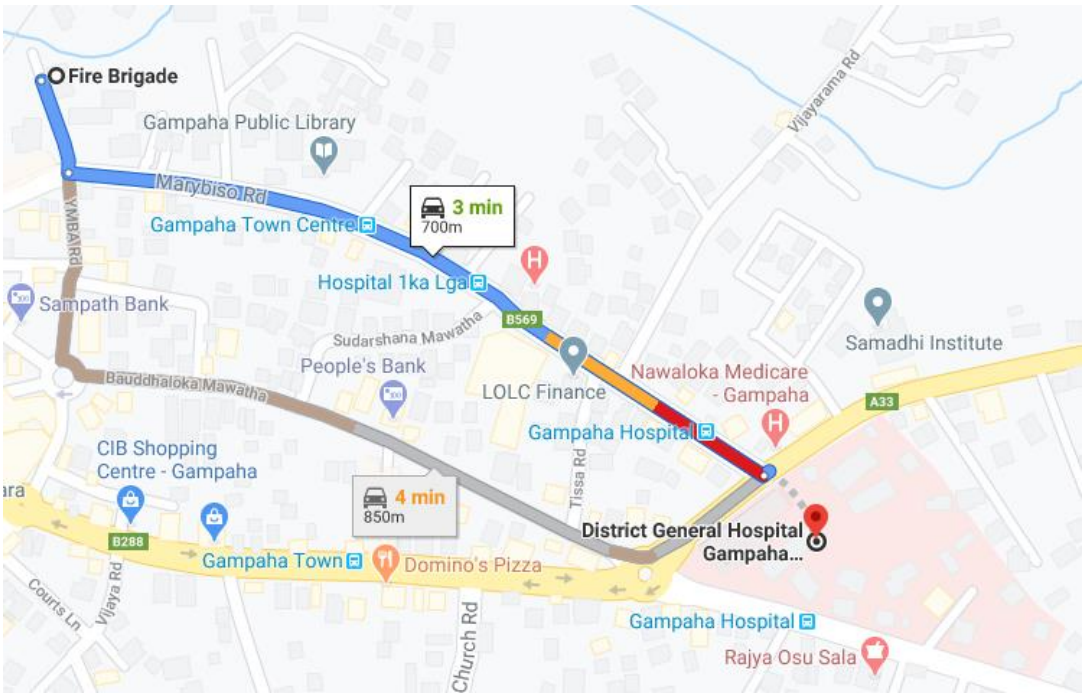

Figure 44: Path of Gampaha Fire Service Department to DGH Gampaha

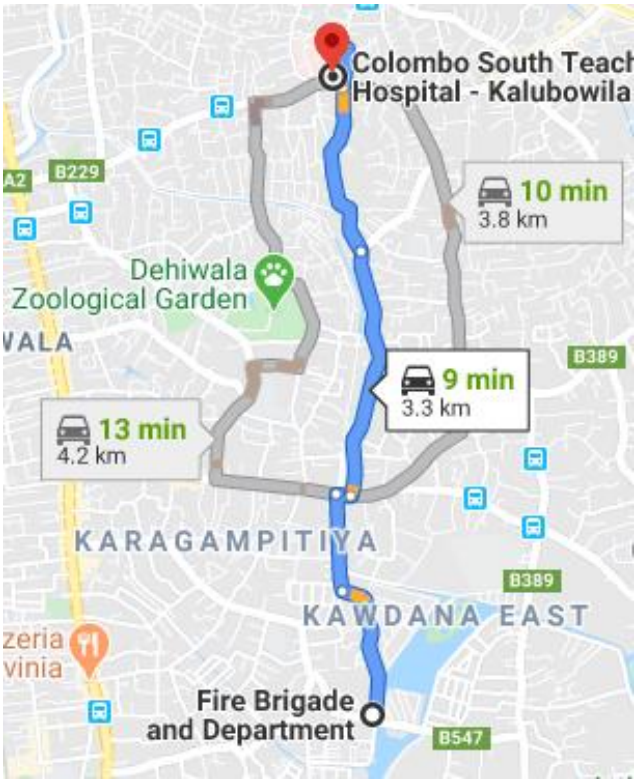

Figure 45: Path of Dehiwala Fire Service Department to TH Kalubowila

Figure 46: Path of Mawanella Fire Service Department to TH Kegalle

5.3 Results

The average speed to travel the distance across 24 hours was also calculated for all three paths. Table 8 describes the analysis of the travel time data collected. Figure 47 shows the variation of average travel speed for the three paths across the 24-hour time period.

Table 8: Travel time data from fire service departments to hospitals

Fire Brigade	Colombo Municipal Council Fire Service Department		Gampaha Fire Service Department		Dehiwala Municipal Council Fire Brigade and Department		Mawanella Municipal Council Fire Service Department	
Hospital	NH of Sri Lanka		DGH Gampaha		TH Kalubowila		TH Kegalle	
Distance (km)	1.4		0.7		3.3		13.8	
	Time (min)	**Average speed (kmph)**	**Time (min)**	**Average speed (kmph)**	**Time (min)**	**Average speed (kmph)**	**Time (min)**	**Average speed (kmph)**
Minimum	4	14	2	10.5	7	16.5	18	34.5
Maximum	6	21	4	21	12	28.3	24	46
Mean	4.7	18.3	2.8	15.9	8.6	23.6	21.3	39.4
Standard deviation	0.8	2.9	0.5	3.4	1.4	3.6	2.4	4.5

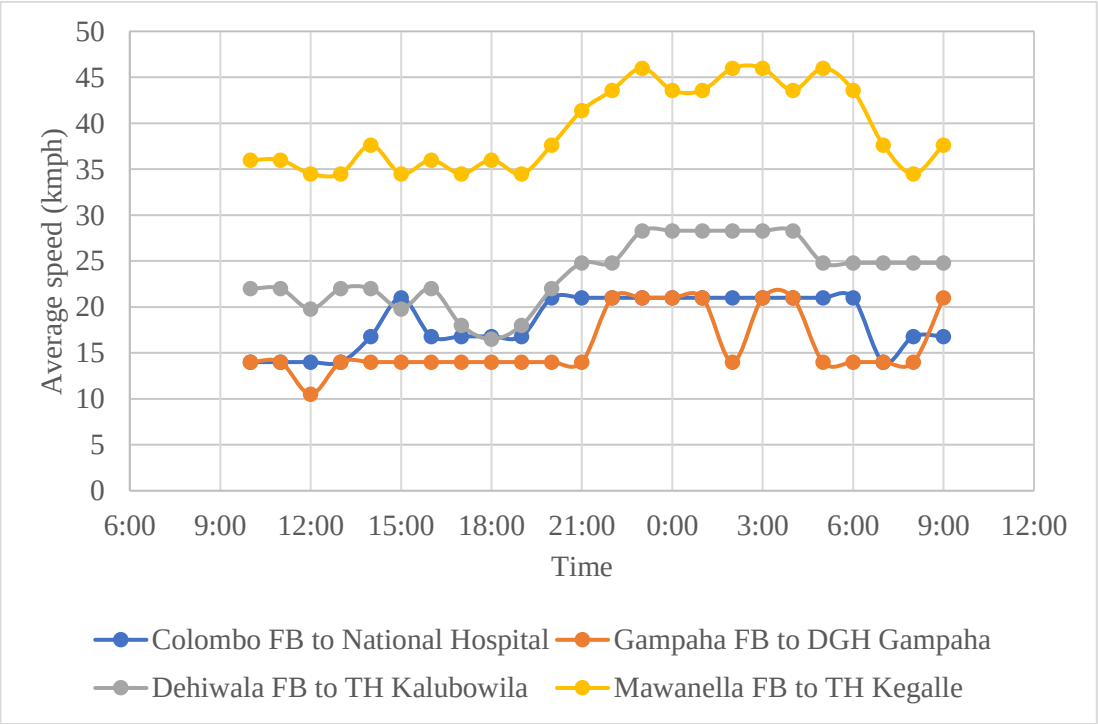

Figure 47: Average speed variations across the 24-hour time period

According to the data collected, only one of the hospitals can be reached in less than 4 minutes by the fire brigade as recommended by the NFPA. However, these data can differ in an actual scenario due to a variety of reasons, including the fact that during an emergency, a clear path would be made available for any official vehicles such as firetrucks. This would reduce the actual response time. On the other hand, the large size of firetrucks would restrict the usage if smaller roads with less traffic, meaning that the response time will increase.

6 Initial Case Studies in Hospitals

6.1 Introduction

The final goal of this research study was to develop a Fire Risk Management Framework that can be applied to any hospital in Sri Lanka. After the development of the FRMF structure, the next step was to expand the elements in the structure into criteria that could be used to increase the fire risk management in a hospital. In order to do this, a basic understanding of hospitals in the country and their approach to fire safety was needed. In this section, the survey conducted helped to identify the fire risk management level of the hospitals, the recognition of the risk of fires in the hospitals, and the approaches to deal with fire risks in the hospitals.

6.2 Methodology

To fulfill this requirement, a case study was conducted in 6 government-owned hospitals in the southern coast of Sri Lanka. The surveyed hospitals are given below.

1. Base Hospital P
2. Divisional Hospital Q
3. Teaching Hospital R
4. District General Hospital S
5. Primary Medical Care Unit T
6. Base Hospital U

An assessment form, which contained 25 criteria relevant to fire safety preparedness was prepared beforehand to be used during the survey. Using the literature review done regarding previous studies in hospitals, DRR frameworks, and regulations regarding fire safety, 5 major sections were considered for the assessment form as follows.

- Prevention of fire hazards
- Firefighting equipment
- Means of escape
- Staff training and preparedness
- Accessibility of fire brigade

An assessment form was filled out for each hospital. The survey was done through visual inspection of the hospital, interviews with staff, and review of disaster management documents in the hospitals. The following hospital staff members were interviewed. The director of each hospital was interviewed, regarding the planning and management activities regarding fire safety. In each of the tertiary hospitals (TH and DGH), the officials of the planning units were also interviewed regarding hospital disaster planning. Finally, in each hospital other than the PMCU T, supportive staff who were responsible for the maintenance of hazardous areas and fire protection systems were interviewed. In PMCU T, the functions of the hospital meant there was a minimal level of fire hazards in the hospital.

Each criterion in the form was marked as Yes, Maybe, or No. The score of Yes was if the condition of the criterion was completely fulfilled for the whole hospital. Maybe was if the condition of the criterion was partially fulfilled for the hospital. No was marked if the condition was not fulfilled or was not sufficiently fulfilled. If the answer was unknown, then also the criterion was marked with No.

6.3 Criteria of the assessment form

Prevention of Fire Hazards

In the first section of fire hazard prevention, there were 7 criteria. These criteria can be categorized as general safety, electrical safety, and fire safety related to fuel and gas. Under general safety, the criteria included the presence of fire safety notices in the hospital, proper control of the storage of flammable materials, and the regular collection of the generated waste at the hospital. In electrical safety, the criteria included checking for the potential of electrical overloading in the electrical network and checking for the presence of electrical equipment being near potential fire hazards or combustible material. Under the sub-section of fire safety related to fuel and gas, the criteria included checking the potential fire hazards in and near the ambulance fuel and kitchen liquid petroleum gas storage areas as well as the generator storage areas.

Fire Protection Systems

Under the second section of fire protection systems, there were 6 criteria. The criteria included checking for the presence of fire detection and alarm systems, active

firefighting systems such as sprinklers, fire extinguishers, and fire hose reels, and passive firefighting systems such as fire or smoke dampers, fire doors and fire walls. The section also checked for alternate methods of fire suppression systems in hazardous areas of the hospital such as buckets of sand in case modern methods such as fire extinguishers were absent.

Means of Escape

The third section, which looked at evacuation, had 6 criteria. These criteria look at the presence of emergency exits, and whether the exits are clearly marked and sufficient for the population of the buildings. The section also checks whether the exits are available readily without being blocked. There is also a check for the presence of evacuation arrangements for people with special needs. Finally, there is a check for the presence of an identified assembly point for people to gather in case of a fire or other emergency.

Staff Training and Preparedness

Under the fourth section of staff training and preparedness, there were 4 criteria. The criteria included the presence of a response plan for a fire in the hospital and the assignment of staff duties in the event of a potential fire. There were also checks to see if the hospital had held fire training and drills for the staff and if at least 25% of the staff were capable of operating firefighting equipment such as fire extinguishers and water hose reels.

Accessibility of Fire Brigade

The fifth section, which looks at the accessibility of the hospital to the local fire brigade, has 2 criteria. The first criterion looks at whether the local fire brigade is present within 4 km. According to the National Fire Protection Association (NFPA) of the United States of America, the response time of a fire brigade must be less than 4 minutes [200]. This means the distance from the fire service department to the hospital must be less than 4 km in order to reach the hospital in that time duration (Assuming a vehicle speed of roughly 60 kmph). The other criterion looks at whether the hospital has adequate access for the fire brigade vehicles. An access width of over

45 m is usually recommended by the Construction Industry Development Authority of Sri Lanka [140].

6.4 Data Collection

During the survey it was identified that out of the 6 hospitals, 4 had previously experienced fires and most of them had been electrical fires. In recent years, BH P, TH R, DGH S, and BH U had experienced fires in the hospitals. Some interesting areas related to fire safety in the surveyed hospitals can be seen below in Figure 48 to Figure 55.

Figure 48: BH P - Manifold room in safe conditions

Figure 50: BH P - Improper waste management

Figure 49: BH P - Abandoned incinerator in unsafe conditions

Figure 51: DGH S - Systematic storage of waste until collection

Figure 52: DGH S - Electrical wiring in unsafe conditions

Figure 54: DGH S - Emergency evacuation notices in the buildings

Figure 53: DH Q - Flammable materials stored next to kitchen gas

Figure 55: BH U - Safe storage of medical gas

Table 9 has identified the nearest fire service station to each hospital. As the response time of a fire brigade must be less than 4 minutes, a fire service department must be at a distance of about 4 km. However, out of the surveyed hospitals, only 50 % fulfill this criterion.

Table 9: Distance between the hospitals and their nearest fire service station

Hospital	Nearest Fire Service Station	Distance
BH P	Fire Brigade 1	35.5 km
DH Q	Fire Brigade 1	4.3 km
TH R	Fire Brigade 1	1.9 km
DGH S	Fire Brigade 2	90 m
PMCU T	Fire Brigade 2	12.2 km
BH U	Fire Brigade 3	800 m

6.5 Results

Table 10 gives the results of the assessment for the 6 hospitals that were surveyed.

Table 10: Assessment results of hospitals surveyed

No.	Criteria	BH P	DH Q	TH R	PMCU T	DGH S	BH U
	Prevention of fire hazards						
1	Presence of fire safety notices	No	No	No	No	No	Maybe 40%
2	Storage of flammable materials are properly controlled	Yes	Yes	Yes	Yes	Yes	Yes
3	Waste is regularly collected	No	Yes	Yes	Yes	Maybe 70%	Yes
	Electrical Safety						
4	No potential for electrical overloading	No	Yes	No	Yes	No	No
5	No electric equipment near combustible material or could cause fire hazards	No	Yes	Maybe 60%	Yes	No	No
	Fire Safety related to fuel and gas						

6	No fuel /gas stores in position to cause potential fire hazards	Yes	Yes	Yes	Yes	No	Yes
7	Generator fuel storage in safe condition	Maybe 50%	Yes	Maybe 50%	Yes	Yes	Maybe 50%
	Firefighting equipment						
8	Fire alarms are present throughout the hospital	No	No	No	No	No	No
9	Active firefighting systems such as sprinklers are present	No	No	No	No	No	No
10	Passive firefighting systems such as fire/smoke dampers, fire doors, fire walls/floors are present	No	No	Maybe 50%	No	Maybe 50%	No
11	Fire extinguishers present	No	Yes	Yes	No	Yes	Yes
12	Fire hose reels present	No	No	No	No	No	Yes
13	Sand bucket kept at hazardous areas	No	Yes	No	No	No	No
	Means of escape						
14	Emergency exits present	No	Maybe 50%	Yes	Maybe 50%	Yes	Yes
15	Emergency exits are marked	No	No	Yes	No	Maybe 40%	No
16	Number of emergency exits are sufficient	No	Yes	Yes	Yes	Yes	Maybe 60%
17	Emergency exits are readily available (not blocked/locked)	Maybe 50%	Yes	Yes	Yes	Maybe 50%	No
18	Special arrangements for the evacuation of people with special needs present	No	No	Maybe 40%	No	No	Maybe 40%
19	Presence of an identified safe place to assemble during a fire	No	Yes	Yes	Yes	No	No
	Staff Training and Preparedness						
20	Presence of a response plan in case of a fire hazard	No	No	No	No	No	Yes
21	Duties have been assigned to staff in case of a fire hazard	No	No	Maybe 50%	No	Maybe 50%	Yes

22	Staff have received training/drills for fire hazard response	No	No	No	No	Yes	Yes
23	Staff members are capable of operating firefighting equipment	No	Maybe 30%	Maybe 30%	Maybe 20%	Maybe 40%	Yes
	Accessibility to fire brigade						
24	Nearest fire brigade present within 4 km	No	No	Yes	No	Yes	Yes
25	Presence of adequate access to the hospital for the fire brigade vehicles to get through	No	Yes	Maybe 50%	Yes	Maybe 50%	Yes

The results of the survey were converted into a quantitative set of results by assigning the answers of criteria by a number. The theory of Fuzzy Logic was used in the assignment of quantitative values. “Yes”, which is the complete fulfillment of a criterion was assigned the value of 1. Similarly, “No”, which is to be used when the criterion is not fulfilled in any part was assigned the value of 0. For a criterion that is partially fulfilled, a decimal value between 0 and 1 which will represent that percentage of fulfillment of the criterion was assigned.

- Yes -1
- Maybe – Between 0 and 1
- No – 0

Thereby, the preparedness level of each hospital was calculated using the equation (5) given below.

$$\text{Preparedness Level} = \frac{\text{Total score}}{\text{Number of applicable criteria}} \times 100\% \quad (5)$$

Figure 56 showcases the individual results of the 6 hospitals. As can be seen, the majority of the hospitals were at a mid-range level, with the preparedness levels varying between 42% in DGH S to 56% in BH U. BH P was at a much lower preparedness level at a score of only 12%.

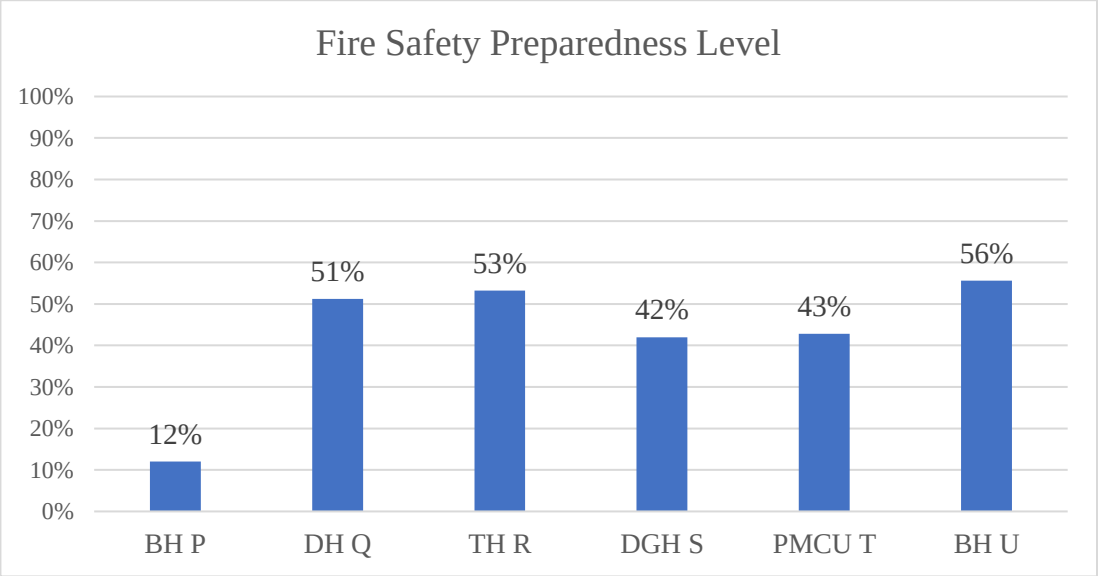

Figure 56: Fire safety preparedness of hospitals surveyed

This shows again that hospitals cannot completely rely on the service of local fire service departments to give aid during a fire, as the fire could turn uncontrollable by the time the fire brigade arrives. Therefore, it is necessary that the hospital is prepared to face an instance where a fire hazard could occur and have the knowledge to handle the fire well, with minimal losses.

7 Fire Risk Assessment Tool for Hospitals

In this section, the development of the FRAT tool and its applicability has been described.

7.1 Development of the FRAT

This section fulfills the research objective of developing a comprehensive, multi-dimensional FRAT that can be used to assess hospitals in Sri Lanka. Using the various DRR frameworks, fire management frameworks, building codes, and building regulations that were reviewed in the literature review section as well as the preliminary desk studies and hospital studies that were conducted, the FRAT was developed following the FRMF structure.

The frameworks, regulations, and codes that were considered in the literature review include the following. The concepts regarding fire safety, disaster risk reduction, and hospital safety have been discussed in section 2.8.

- Hospital Safety Index (HSI) Guide for Evaluators [23]
- National Disaster Management Guidelines: Hospital Safety (India) [52]
- National Fire Protection Agency (USA) Guidelines [65], [135], [200]
- British Standards Institution Guidelines [136], [166]
- National Building Code of India – Part 4 Life and Fire Safety [137]
- Firecode – fire safety in the NHS (UK) [139]
- Construction Industry Development Authority (Sri Lanka) Regulations [140], [141]

The FRAT consists of 3 modules. These modules are:

1. Design and Construction (DC)
2. Operation and Maintenance (OM)
3. Fire Hazard Management (FHM)

The FRAT was categorized into these three modules taking the categorization of the HSI guide as the basis (structural, nonstructural, and emergency and disaster management). Fire safety is a dimension that should be considered from the very beginning. This includes the design and construction phase. Therefore, a separate

module was included for this phase as DC. The activities in the operation phase of a hospital have been identified in two varieties. The first variety is the type of activities needed for the regular operation of the hospital. These activities were defined under the module OM. The other variety of activities are planning and management activities conducted by the administrative department of the hospital. The activities under this type were defined in the module FHM.

Each of these modules has several submodules with assessment criteria for each submodule. The submodules are listed below.

1. Design and Construction

This module looks at the fire safety characteristics of the buildings, in terms of both prevention and protection of fire. The literature mainly used in this section was the CIDA Fire Regulations and the HSI Guide's second module: structural safety. The three submodules here were developed following the 2nd, 3rd and 7th chapters of the CIDA Fire Regulations: Means of escape, Structural fire precautions, and Accessibility for firefighting.

Means of escape

Emergency evacuation is an important part of disaster risk response. Therefore, in building planning, special consideration must be paid to elements of building exits such as exit doors, corridors, stairways, and handrails. Including evacuation methods for people with mobility issues is important considering that there will be a lot of patients with difficulty evacuating themselves in hospitals. The protection of emergency exit ways from the spread of fire was also included in methods of smoke stop lobbies and mechanical ventilation [139], [140].

Fire hazard prevention

This section looks at the prevention of fire hazards spreading through the building. It includes looking at the combustibility of building materials and compartmentalization of hazardous areas such as kitchens, transformer rooms, generator rooms, and storage areas [140]. It also looks at the spread of fire between buildings [23].

Accessibility to fire brigade

This section is about the access points of the hospital to the fire brigade and its vehicles, including access to the premises, basements, and hazardous areas. It also looks at the working space available to the fire brigade in front of a building [140].

2. Operation and Maintenance

This module is about elements needed to be implemented for fire safety in the hospital, during the operation of the hospital. The literature mainly used in this section are CIDA Fire Regulations, NHS Firecode (UK), CIDA Specifications for fire detection, protection and suppression systems, and the third module of the HSI Guide: nonstructural safety. The first submodule (Means of escape) was developed following the submodule of infrastructure protection, access, and physical security in the HSI guide by looking at the safety of movement paths in a hospital. The second and third submodules (Fire detection and alarm systems and active fire protection systems) were developed following the 4th and 5th chapters in the CIDA Fire Regulations, the relevant specifications given in the CIDA Specifications and the submodule of critical systems in the HSI guide. The fourth submodule (fire hazard prevention) was developed using the 6th chapter in CIDA Fire Regulations as well as the data gathered from the desk study looking at causes of fires in hospitals and the preliminary case studies. The fifth submodule (firefighting) was developed completely from the insights gained during the preliminary case study.

Means of escape

This section again looks at the current condition of the evacuation elements, including the accessibility of escape areas, conditions of the floors, emergency lighting in exit ways, and provisions for evacuation for people with special needs. It also includes the requirement of an identified assembly point in case of an emergency and signs aiding evacuation [23], [140].

Fire detection and alarm systems

This section includes the assessment criteria for automatic fire detection and alarm systems, manual call points, and emergency alarms and emergency communication systems in the hospital [23], [140].

Active fire protection systems

This section is about the presence and maintenance of active fire suppression systems including sprinkler systems, fire extinguishers, fire blankets, fire hose reels, and external pillar hydrants [23], [140].

Fire hazard prevention

This section looks at fire prevention activities needed in a hospital. This includes the security of flammable material storage areas, waste collection, kitchen areas, heating appliances, and fuel storage areas. It also includes looking at electrical fire safety and the control of arson in the hospital [138].

Firefighting

This section looks at the familiarity of the local fire service department with the hospital and the availability of space for the fire brigade inside the hospital.

3. Fire Hazard Management

This module is regarding the planning and management activities which are needed to be done for fire risk management in the hospital. The literature mainly used for this section are the CIDA Fire Regulations and fourth module of the HSI guide: emergency and disaster management. The first and second submodules (Disaster planning and Staff training) were developed following the submodule coordination and disaster management activities in the HSI guide. The criterion in the submodule was rephrased to fit fire safety management. The third submodule (Inspection, maintenance, and testing) was developed following the 8th chapter in the CIDA Fire Regulations (Inspection, maintenance, and testing of active and passive fire protection facilities).

Disaster planning

This section inquiries about the hospital's planning regarding disaster and fire hazard management and procedures. It also looks at the hospital's incident reporting systems and procedures for alteration and repair works at the hospital. Finally, the insurance coverage of the hospital is looked at as well [23].

Staff training

This section looks at the training and drills provided to hospital staff regarding fire safety. This includes instruction in fire prevention and fire suppression equipment such as fire extinguishers, participation in fire drills, and instruction and training in patient evacuation procedures [23].

Inspection, maintenance, and testing

This section looks at the regularity of external and internal inspections, presence of service contracts, and record-keeping of maintenance works of fire suppression systems in the hospital [138].

The 1st module (Design and Construction) has a total of 29 criteria. This part of the assessment should be conducted separately for each building of the hospital. The 2nd module (Operation and Maintenance) and 3rd module (Fire Hazard Management) have 48 and 18 criteria respectively. These 2 modules' assessment should be conducted considering the hospital as a whole.

The scoring for each criterion should be between 0 and 1. A guide to scoring the hospital for each criterion was also done.

The criteria of the FRAT tool along with the scoring guide have been listed in Table 11 - Table 21.

The primary reference or basis for each criterion has been provided. The symbol for each basis has been described below.

- P – Preliminary case study
- T – Traffic study
- F – Study of past fire hazards in hospitals

7.1.1 Design and Construction

7.1.1.1 Means of Escape

Table 11: FRAT Module - DC, Submodule - Means of escape

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
Exit door						
Clear width of doors is 1100mm-1250mm	False	True for 25% of the building or more	True for 50% of the building or more	True for 75% of the building or more	True for the complete building	[140]
Exit doors open in direction of escape	False	True for 25% of the building or more	True for 50% of the building or more	True for 75% of the building or more	True for the complete building	[140]
Exit doors are self-closing	False	True for 25% of the building or more	True for 50% of the building or more	True for 75% of the building or more	True for the complete building	[140]
Exit ways						
Number of exit ways from hospital wards	1				2 or more	P
Exit stairways						
Number of stairways each floor (Can include ramps, external staircases)	1				2 or more	[140]
Provision of ramps (Applicable if patients stay in the building)	0				1 or more	P
Handrails for stairways are provided	False	True for 25% of the building or more	True for 50% of the building or more	True for 75% of the building or more	True for the complete building	[140]

Access for wheelchairs or trolleys in corridors and stairways						
Access width is greater than 950 mm	False	True for 25% of the building or more	True for 50% of the building or more	True for 75% of the building or more	True for the complete building	[140]
Smoke stop lobby (If there are 2 or more floors)						
Provision of smoke stop lobby in each floor	No smoke stop lobby		At least one stairway is entered through a smoke stop lobby		2 Stairways or more are entered during a smoke stop lobby	[140]
Impedance to escape movements	Smoke stop lobby impedes escape movements/Smoke stop lobby not present				Smoke stop lobby does not impede escape movements	[140]
Pressurized ventilation	Pressurized ventilation not provided/Smoke stop lobby not present				Pressurized ventilation provided	[140]

7.1.1.2 Fire Hazard Prevention

Table 12: FRAT Module - DC, Submodule - Fire hazard prevention

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
General						
Proximity to buildings	Separation less than 5m		Separation between 5m - 15m		Separation more than 15m	[23]
Kitchen area is separated from other areas (By walls)	No				Yes	[140]
Areas of special hazard are compartmentalized (Boiler room, Transformer room, Generator room, Storage area of flammable/combustible materials)	FALSE	True for 25% of the hazard areas or more	True for 50% of the hazard areas or more	True for 75% of the hazard areas or more	True for all the hazard areas	[140]
Building material						
Combustibility of building material	Combustible material such as wood				Non-combustible material such as concrete	[140]
Combustibility of roofing material	Combustible material				Non-combustible material such as concrete	[140]
Walls and floors						
Fire shutters and curtains are provided	False	True for 25% of the building or more	True for 50% of the building or more	True for 75% of the building or more	True for the complete building	[140]

Enclosures for ducts passing through are provided	False	True for 25% of the building or more	True for 50% of the building or more	True for 75% of the building or more	True for the complete building	[140]
Combustibility of floor finishes	Combustible material such as wood				Non-combustible material such as rendered concrete, tiles	[140]
If building height > 30n						
Fire lift						
At least on fire lift is provided	No				Yes	[140]
Natural/mechanical ventilation is provided in fire lift	No				Yes	[140]
Fire lift is connected to primary and secondary power supply	No				Yes	[140]
If building is a high rise/super high rise/basement with depth over 9m						
Firefighting shaft						
Firefighting shafts provided allowing access to all parts of each story	No				Yes	[140]
If building is a super high rise						
Evacuation lift						
Evacuation lift which serves every floor is provided	No				Yes	[140]
Evacuation lift can accommodate a stretcher	No				Yes	[140]

7.1.1.3 Accessibility to the fire brigade

Table 13: FRAT Module - DC, Submodule - Accessibility to the fire brigade

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
Access way width	Less than 4.5m				Equal to or more than 4.5m	[140]
Clear working space	Less than 4m x 4m		Equal to or more than 4m X 4m		Equal to or more than 7m x 15m	[140]
Access to staircase to basement is within 18m of fire vehicle stop	No				Yes	[140]
There is easy access to areas of special hazard	No				Yes	[140]

7.1.2 Operation and Maintenance

7.1.2.1 Means of Escape

Table 14: FRAT Module – OM, Submodule - Means of escape

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
Accessibility of areas designated for escape (Exit staircase, smoke stop lobby, exit passageway, and corridor)	Areas are completely obstructed; people can't pass through		Areas are partially obstructed, but people can pass through		Areas are completely free; people can pass through	[23]
Final exits lead to a place of total safety	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	P
Condition of floors and stairway surfaces	Conditions are bad, there is a possibility for tripping and slipping hazards				Conditions are good, there is no possibility of tripping or slipping	P
Emergency lighting is provided in the stairways	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
Appropriate provisions have been made for the safety of people with special needs	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	F

Assembly points	No assembly points have been designated		1 Assembly point has been designated		A primary and secondary assembly point has been designated	[140]
Signs						
Escape ways have been indicated by signs	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
Floor levels are indicated by signs	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
Evacuation maps are present	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	P
Assembly point signs are present	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
Fire Action notices are displayed	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	P
Fire safety notices and signs are present and clearly visible	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
"Push bar to open" sign present on fire doors	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[141]

7.1.2.2 Fire Detection and Alarm Systems

Table 15: FRAT Module – OM, Submodule - Fire detection and alarm systems

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
Smoke/Heat detectors are installed	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[23]
Manual call points are provided	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
Emergency alarm provided	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	P
Fire alarm	No fire alarm systems present		Only audio alarm present		Both audio and visual alarm provided	[140]
Alarm control panel (manned 24/7) is provided	No				Yes	[140]
Emergency Communication System (ECS)	ECS is not provided		One-way ECS (E.g. Speakers) is provided		Two-way ECS is provided	[140]

7.1.2.3 Active Fire Protection Systems

Table 16: FRAT Module – OM, Submodule - Active fire protection systems

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
Automatic sprinkler system present	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
Separate water supply for sprinklers and hose reels provided	No				Yes	[140]
Fire blankets have been provided in high-risk areas (such as kitchen, laboratory)	False	True for 25% of high-risk areas or more	True for 50% of high-risk areas or more	True for 75% of high-risk areas or more	True for all the high-risk areas	P
Fire extinguishers						
Fire extinguishers have been sufficiently provided and are easily accessible	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[23]
Posters describing the use of extinguishers available	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	P
Hose reels						
Located sufficiently in each floor	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]
Located so that each area of the buildings can be reached	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[141]

Hose reel cabinet is unlocked	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[141]
If access to fire vehicle is restricted						
External pillar hydrants are provided	False	True for 25% of the hospital or more	True for 50% of the hospital or more	True for 75% of the hospital or more	True for the complete hospital	[140]

The scoring in Table 17 and Table 18 have been denoted as Yes, Maybe and No. these scoring points have been defined as follows. The score of Yes is if the condition of the criterion is completely fulfilled for the whole hospital. Maybe is if the condition of the criterion was at least 50% partially fulfilled for the hospital. No is defined as the condition not being fulfilled or was not sufficiently fulfilled, or if the answer is unknown.

7.1.2.4 Fire Hazard Prevention

Table 17: FRAT Module – OM, Submodule -- Fire hazard prevention

Criteria	Score			Reference / Basis
	0	0.5	1	
General				
Highly flammable materials are kept out of the basements	No	Maybe	Yes	[140]
Hospital does not have fire spreading material in doors or windows (E.g. Curtains)	No	Maybe	Yes	P
Quantities and storage of flammable materials are controlled	No	Maybe	Yes	F
Suitable means to control arson are present	No	Maybe	Yes	F
Waste management				
Waste is separated	No	Maybe	Yes	P
Waste storage is in a good condition and properly controlled	No	Maybe	Yes	P
Waste is regularly collected	No	Maybe	Yes	P
Waste storage area has minimum exposure to fire hazards	No	Maybe	Yes	P
Kitchen				
Automatic fire suppression system provided in cooking range	No	Maybe	Yes	[141]
Kitchen gas storage				
Gas cylinders have minimum exposure to excessive temperature rise and tampering	No	Maybe	Yes	[140]

Gas cylinders are stored against an outside wall	No	Maybe	Yes	[140]
Heating appliances				
All heating appliances are securely fixed in position and secured	No	Maybe	Yes	[140]
There is no flammable material stored near heating appliances	No	Maybe	Yes	F
Fuel storage				
Fuel storage is secured and has minimum exposure to fire	No	Maybe	Yes	P
Electrical safety				
The entire electrical installation is in order	No	Maybe	Yes	[23]
The electrical circuits are free of evidence of overloading	No	Maybe	Yes	P
Electrical equipment is kept away from combustible materials	No	Maybe	Yes	F

7.1.2.5 Fire fighting

Table 18: FRAT Module – OM, Submodule - Firefighting

Criteria	Score			Reference / Basis
	0	0.5	1	
Vehicle parking has not blocked access to fire brigade vehicles	No	Maybe	Yes	P
Access openings are unobstructed	No	Maybe	Yes	P
Fire service department is familiar with the premises	No	Maybe	Yes	T

7.1.3 Fire Hazard Management

7.1.3.1 Disaster Planning

Table 19: FRAT Module – FHM, Submodule - Disaster planning

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
Hospital Disaster Management Plan (HDMO)	No HDMP has been developed	HDMP Plan has been developed but not updated in the last 2 years. Does not contain a section for fire safety	HDMP Plan has been developed but not updated in the last 2 years. Contains a section for fire safety	HDMP Plan has been developed and updated. Does not contain a section for fire safety	HDMP Plan has been developed and updated. Contains a section for fire safety	[23]
Incident Reporting System (IRS)	No IRS present in the hospital		An informal IRS present in the hospital		a formal IRS present in the hospital	[23]
Fire Action Plan (FAP)	No FAP present in the hospital		An informal FAP present in the hospital		A written FAP present in the hospital	[139]
Emergency Evacuation Procedures (EEP)	Hospital does not have EEP		Hospital has informal EEP		Hospital has written EEP	P

Emergency Response Team (ERT)	Hospital does not have an ERT		Hospital has staff designated for hospital hazards, but an ERT has not been formally designated		Hospital has a designated ERT	P
Defined procedures to control alteration, repair and decoration work	Hospital does not have defined procedures		Hospital has informal procedures		Hospital has defined written procedures	[140]
Insurance	Hospital does not have insurance	Hospital is in the process of obtaining insurance	Hospital insurance covers hospital property	Hospital insurance covers hospital property and patients	Hospital insurance covers hospital property, patients and staff	[30]

7.1.3.2 Staff Training

Table 20: FRAT Module – FHM, Submodule - Staff training

Criteria	Score					Reference / Basis
	0	0.25	0.5	0.75	1	
Staff have received fire prevention instruction	False	True for at least 25% of the staff	True for at least 50% of the staff	True for at least 75% of the staff	True for at least all of the staff	[139]
Staff have received training in use of fire protection equipment	False	True for at least 25% of the staff	True for at least 50% of the staff	True for at least 75% of the staff	True for at least all of the staff	[139]
Staff have participated in fire drills	False	True for at least 25% of the staff	True for at least 50% of the staff	True for at least 75% of the staff	True for at least all of the staff	[139]
Regularity of fire drills and fire protection training	Not conducted at least annually		Conducted annually		Conducted every 6 months or less	[140]
Staff have knowledge regarding contacting and obtaining services of the fire service department	False	True for at least 25% of the staff	True for at least 50% of the staff	True for at least 75% of the staff	True for at least all of the staff	[139]
Staff are aware of patient evacuation procedures	False	True for at least 25% of the staff	True for at least 50% of the staff	True for at least 75% of the staff	True for at least all of the staff	[139]
Fire commander (FC)	Hospital does not have a FC		Hospital does not have a FC. Hospital has a staff member in charge of fire safety		Hospital has an FC	[140]

7.1.3.3 Inspection, Maintenance, and Testing

Table 21: FRAT Module–FHM, Submodule-Inspection, maintenance, and testing

Criteria	Score		Reference / Basis
	0	1	
At least annual external inspections are conducted	No	Yes	[140]
Regular maintenance is conducted as necessary	No	Yes	P
Hospital has a servicing contract with a contractor	No	Yes	[23]
Records of maintenance tests are kept	No	Yes	[140]

7.2 Application of the FRAT

In order to find the applicability of the developed FRAT, an application assessment was conducted. The FRAT is intended to suit any hospital in the country. The FRAT was applied to three private-owned hospitals (Hospitals A, B, and C) and three government-owned hospitals (DH Q, BH U, and DGH S). This way, it could be identified if the FRAT would suit both types of hospitals in Sri Lanka.

The application assessment was conducted on three major private-owned hospitals in the country. The assessment for DC and OM was done through visual inspection of each of the hospital buildings. The FHM assessment was done through discussions with the hospital staff. In each hospital, discussions were had with the hospital's director or head administrative official, maintenance staff, security staff, and supportive staff (E.g. Kitchen staff). The cross-section of the participants can be seen in Figure 57. The discussions approached areas regarding disaster planning and management, staff training, and services of local fire service departments.

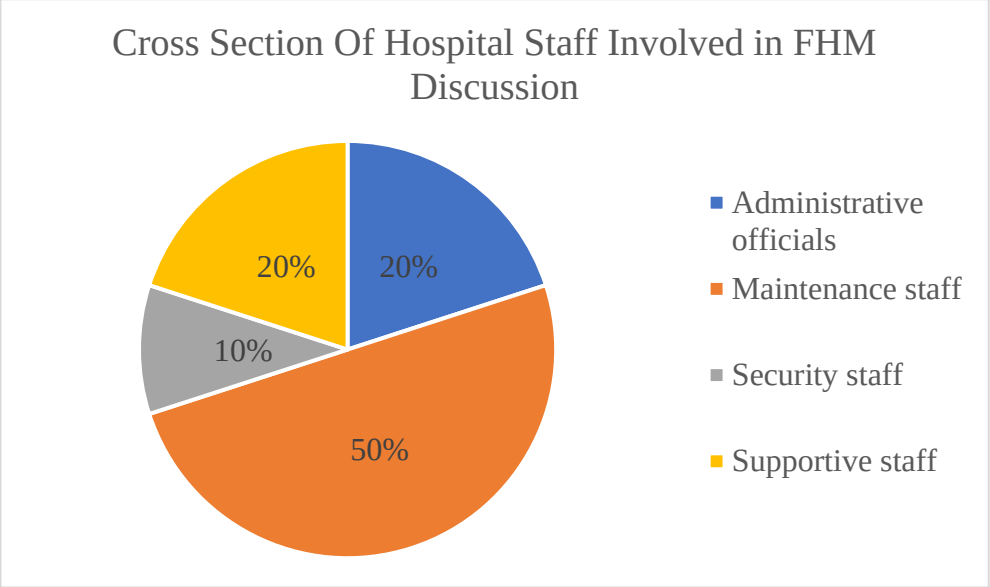

Figure 57: Cross-section of hospital staff involved in FHM discussion

7.2.1 Application in Private-Owned Hospitals

7.2.1.1 Hospital A

Hospital A was established in 1955 and is administrated by the hospital director. The hospital consists of 4 buildings. The main building was (Building 1) constructed in 2006 and has 5 floors. Most of the medical-related activities are done in this building. The other three buildings are small, older buildings. One of the buildings (Building 2) is a two-story building used for office work. The next building (Building 3) is another two-story building where out-patient service is offered. The fourth building (Building 4) is a single-story building that contains the hospital kitchen.

The complete results of the hospital assessment can be found in Appendix I. The summarization of the assessment can be seen below in Figure 58. The scores for DC in the hospital varied between 0.32 and 0.69 in the four buildings. The lowest score was for Building 3 at 0.32 followed by 0.38 for Building 4 and 0.54 for Building 2. The highest score was for the most recently constructed building, Building 1 at 0.69. The scores for OM and FHM were 0.45 and 0.42 indicating below 50% of the requirements were sufficiently fulfilled.

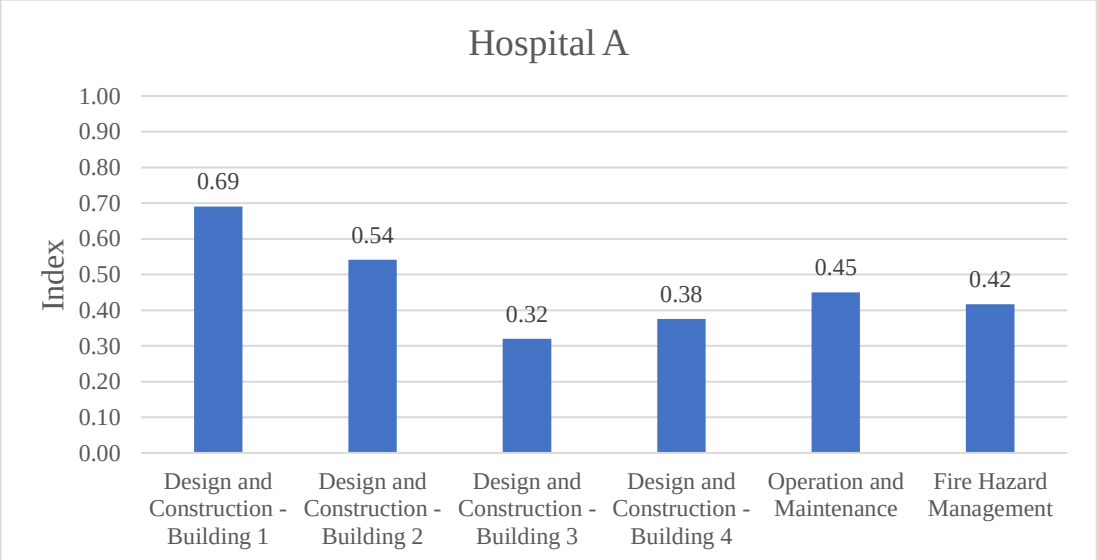

Figure 58: Assessment result summary of Hospital A

7.2.1.2 Hospital B

Hospital B was established in 1984 and its administration is done through a Board of Directors. The main building (Building 1) was built in 2009 after the previous building was demolished. This building has 4 stories. The second building (Building 2) was slowly built afterward. The second building has 6 stories and one basement. A separate building (Building 3) for eyecare was purchased in 2014. This building has 3 floors and 1 basement. The fourth and final building (Building 4) was constructed in 2019 and it currently only has laboratory work being done within it.

The complete results of the hospital assessment can be found in Appendix II. The summarization of the assessment can be seen below in Figure 59. The scores for DC in the hospital were between 0.60 and 0.81. The DC score was lowest for Building 1 at 0.60, followed by 0.67 for Building 2 and 0.1 for Building 3. The highest DC score was for Building 4 at 0.81. It was noticed that the DC scores varied in such a way that the DC score was highest for the most recently constructed building. The OM score was 0.58 and the FHM score was 0.53, indicating that slightly over 50% of the requirements were sufficiently fulfilled in both modules.

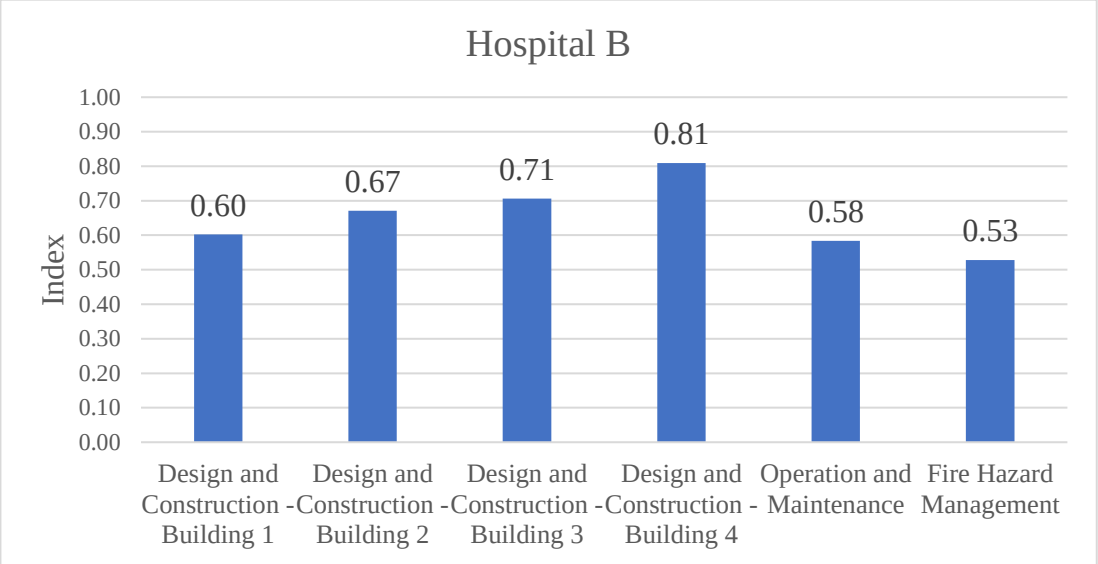

Figure 59: Assessment result summary of Hospital B

7.2.1.3 Hospital C

Hospital C was started in 2019. The hospital is part of a hospital chain and is administrated by a General Manager. The hospital consists of one building, which has 10 stories.

The complete results of the hospital assessment can be found in Appendix III. The summarization of the assessment can be seen below in Figure 60. The DC score for the hospital was 0.92, OM score was 0.94 and the FHM score was 0.99. The scores gained for each module has shown a high level of performance in all sections of fire risk management in the hospital.

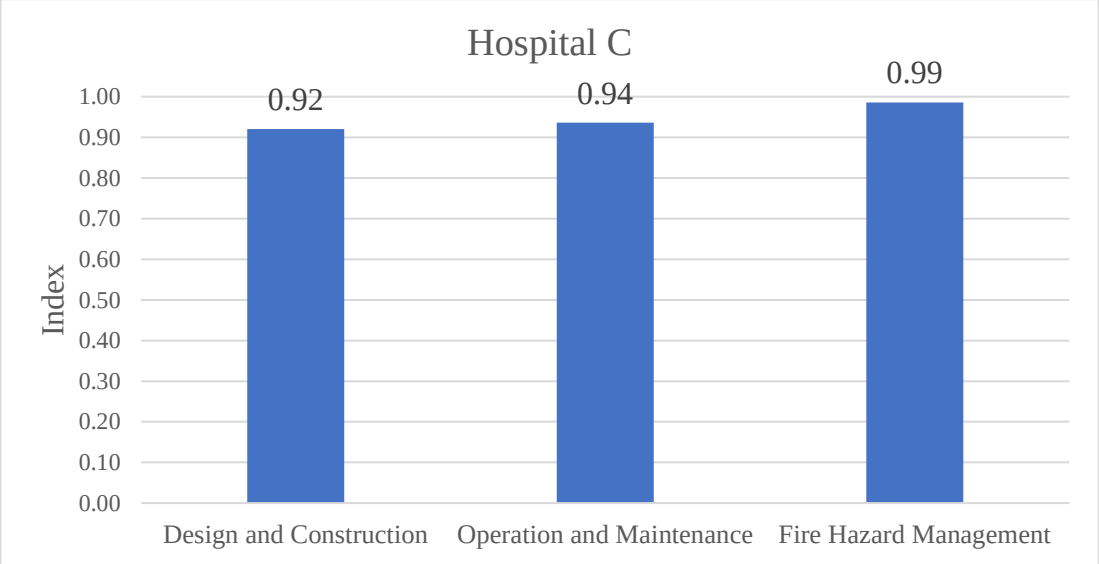

Figure 60: Assessment result summary of Hospital C

7.2.1.4 Discussion of the Results

When looking at the assessment results of the three hospitals, a clear difference can be seen between each. These differences in the fire safety performance can be attributed to the construction years of the buildings and the administrative system of the hospitals.

Design and Construction

Considering this module, the overall scores for Hospital A were 0.69, 0.54, 0.32, and 0.38 for Buildings 1 – 4 respectively as shown in Figure 58. For Hospital B, the overall scores were 0.60, 0.67, 0.71, and 0.81 for Buildings 1 – 4 respectively as shown in

Figure 59. The single building in Hospital C received an overall score of 0.92 as shown in Figure 60. The results show that the best overall performance was from Hospital C and the poorest performance was by Hospital A. Considering the scores of individual buildings, it was observed that the DC scores were higher in more recently constructed structures than in older structures.

When looking at the building itself, self-closing doors, fire doors, and smoke lobbies were seen absent in Hospital A as well as in the older buildings in Hospital B. However, these older buildings contained ramps in patient floors, whereas the new buildings in Hospital B and Hospital C did not have ramps installed. The reasoning is that the presence of lifts usually negates the need for ramps. However, this will make evacuation activities difficult as the usage of lifts is not advised during a fire. Considering the submodule of means of escape in Hospital A, Building 1 had a score of 0.73, Building 2 had a score of 0.50, and Buildings 3 and 4 each had a score of 0.25. For the submodule in Hospital B, the Buildings 1 – 4 received scores of 0.48, 0.61, 0.52, and 0.86 respectively. Hospital C received a score of 0.91 in the same submodule.

Close proximity of buildings is not a good factor is fire risk management, as this enables the spread of fire. However, both Hospitals A and B this was seen, as some buildings were also seen to be connected on the ground floor as well as on other floors through passageways. The smaller buildings in Hospital A also had some combustible building materials such as wood used as well. The combustibility of the floors of all hospital building was low, with materials like tiles and cement rendering being used. Considering the submodule of fire hazard prevention, Hospital A received scores for Buildings 1 - 4 of 0.64, 0.54, 0.54, and 0.61 respectively. For the same submodule, Hospital B received scores of 0.71, 0.75, 0.81, and 0.86 for Buildings 1 – 4 respectively. For Hospital C, the submodule of fire hazard prevention received a score of 0.91.

All three hospitals had clear, wide access ways to the fire brigade vehicles and a clear working space available for the firefighters. However, in Hospital A, as the Buildings 3 and 4 are located behind Buildings 1 and 2, accessing these 2 buildings during a fire could be somewhat difficult for firefighters. Considering the submodule of accessibility to fire brigade, Hospital A received moderately high scores of 0.67 and

0.75 for Buildings 1 and 2. However, the scores of Hospital A for Buildings 3 and 4 were very poor at 0.00. For the same submodule, Hospital B received scores of 0.75, 0.67, 1.00, and 0.83 for Buildings 1 – 4 respectively. Hospital C received a high score of 1.00 for the same submodule.

Operation and Maintenance

The overall scores of the OM module were 0.45 for Hospital A, 0.58 for Hospital B, and 0.94 for Hospital C as shown in Figure 58, Figure 59, and Figure 60. Considering the operation and maintenance of the hospitals, again Hospital C showed a near-perfect fire safety performance. On the other hand, Hospitals A and B only showed mid-range values.

Considering the exit ways, stairways and lighting, in all three hospitals, the conditions of these elements were good. However, only Hospital C had officially designated an assembly point, while the other 2 hospitals only had informally acknowledged emergency assembly points, which were not known to many of the staff. A similar situation was observed regarding the emergency signage, as only Hospital C had all emergency signs required. Considering the submodule of means of escape, the scores for Hospitals A, B, and C were 0.35, 0.37, and 0.92 respectively.

Considering fire detection and alarm systems, these systems were only present in Hospitals B and C. Hospital A only had a manual emergency alarm system installed. Hospitals B and C had emergency communication systems, but only Hospital C had a two-way communication system. Hospital C also had an alarm control panel which was operated at all hours. In the submodule of fire detection and alarm systems, Hospital A received a score of 0.25, Hospital B received a score of 0.67, and Hospital C received a score of 0.92.

Hospital B only had a sprinkler system installed in Building 4, the newest building and sprinkler systems were missing in Hospital A. Hospital C had sprinkler systems installed in the whole building and it was the only hospital that had a separate water supply for fire protection systems. Fire blankets were provided in Hospital A in the laboratory and in Hospital C in the kitchen, but in both hospitals, all hazardous areas were not equipped. In all three hospitals, fire extinguishers were sufficiently provided.

In Hospitals A and B, water hose reels were only provided in the first two floors and Hospital C has them installed in each floor at a sufficient quantity. Considering the submodule of active fire protection systems, the scores for Hospitals A, B and C were 0.38, 0.58, and 0.83.

It was observed that Building 2 in Hospital B had its medical storage in the basement level. As this storage could contain flammable material, the safety of the building could be compromised. All three hospitals are secured against arson with 24-hour security. Similarly, all three hospitals have good waste management and disposal systems which are done regularly, lowering the risk of fire hazards. The fire hazard risk in the hospital kitchens is low in all three hospitals due to the actions of the staff. Also, in both Hospitals B and C, the cooking ranges had automatic fire suppression systems. All three hospitals had incinerators and in Hospital A and B, some flammable material was seen in the compartment holding the incinerator. A similar situation was seen in the generator rooms of Hospital A and B. When considering the electrical fire risk in the hospitals, it was noted that in both Hospitals A and B, there was evidence of electric circuit overloading, with both hospitals having experienced small electric fires in the past. In the submodule of fire hazard prevention, Hospital A received a score of 0.59, Hospital B received a score of 0.65, and Hospital C received a score of 1.00.

In Hospitals A, the area in front of the hospital buildings is used as a car park. In a situation requiring the fire brigade, this could pose a problem for the fire brigade vehicle to access the hospital building. When considering the familiarity of the local fire service departments with the hospitals, all three hospitals have a good connection with the fire service departments, as they annually visit the hospitals for fire assessments. Considering the submodule of firefighting, the scores for Hospitals A, B, and C were 0.67, 1.00, and 1.00 respectively.

Fire Hazard Management

The overall scores for the module FHM were 0.42 for Hospital A, 0.53 for Hospital B, and 0.99 for Hospital C as shown in Figure 58, Figure 59, and Figure 60. The best performance was by Hospital C and the poorest performance was by Hospital A.

Hospital C displayed a high level of performance in this section. It had written and practiced procedures for hospital disaster management including fire hazard management, incident reporting, fire action, emergency evacuation, and alteration and repair work in the hospitals. However, this level of performance was not seen in either Hospital A or B, with most of these elements being absent or only present in an informal and unwritten state. The scores for the submodule of disaster planning for Hospitals A, B, and C were 0.21, 0.46, and 0.96 respectively.

The high level of performance in Hospital C can be attributed to the level of dedication the hospital has directed towards fire risk management. The hospital has a designated Fire Commander, a position that is missing in both other hospitals. Regarding fire protection training and fire drills in the hospitals, Hospital C has included all the staff in the training and fire drills are held quarterly. Hospitals A and B provide training to select staff members such as maintenance staff and security staff and this is done only annually. Considering the submodule of staff training, the score was 0.43 for Hospital A, 0.46 for Hospital B, and 1.00 for Hospital C.

In order to continue the operation of the hospital, private-owned hospitals are required to obtain a “Fire License” from the local fire service department each year. All three hospitals have annual external inspections conducted due to this. Maintenance and servicing are done regularly for all the hospitals. The scorings for the submodule of inspection, maintenance, and testing in Hospitals A, B, and C were 0.75, 0.75, and 1.00.

7.2.2 Application in Government-Owned Hospitals

7.2.2.1 DH Q

The FRAT was applied to the DH Q. The DC module was used to assess the hospital building containing the administrative offices, which is a single-story building. The complete results of the hospital assessment can be found in Appendix IV.

The summarization of the assessment can be seen below in Figure 61. The DC score for the hospital was moderately high at 0.88, while the OM score was much lower at 0.48. The score for FHM was very poor at 0.14, indicating that active planning and management activities regarding fire hazard management in the hospital were very low.

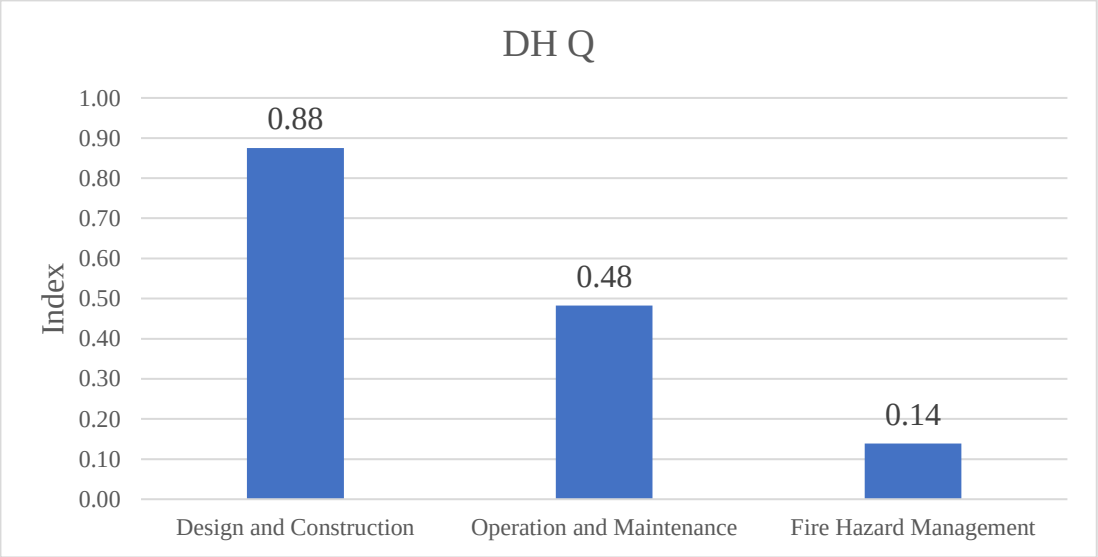

Figure 61: Assessment result summary of DH Q

7.2.2.2 BH U

The FRAT was applied to the BH U. The DC module was used to assess the hospital building containing the administrative offices and the planning unit. The complete results of the hospital assessment can be found in Appendix V.

The summarization of the assessment can be seen below in Figure 62. The DC score for the hospital was 0.67 while the OM score was 0.51, indicating slightly above-average values for both modules. The FHM score was lower at 0.32. However, this

FHM score was higher than the score of both other government-owned hospitals that were assessed using the FRAT.

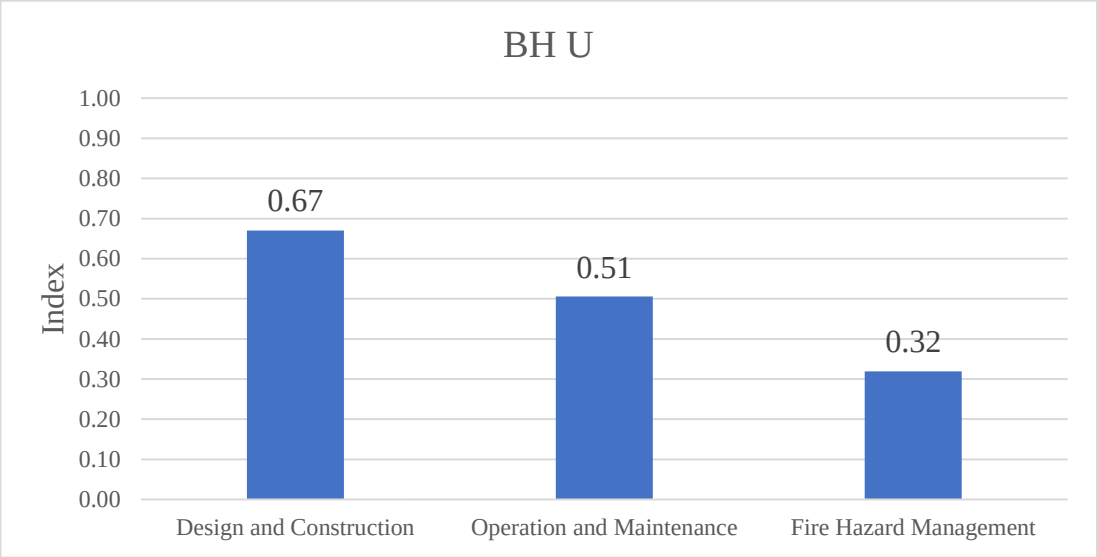

Figure 62: Assessment result summary of BH U

7.2.2.3 DGH S

The FRAT was applied to the BH U. The DC module was used to assess the hospital building containing the administrative offices and the planning unit. The complete results of the hospital assessment can be found in Appendix VI. The summarization of the assessment can be seen below in Figure 63. The DC score for the hospital was 0.60, indicating a slightly above average score. The OM score was 0.38 and FHM score was 0.25. The OM score of the hospital was the lowest score of the three government-owned hospitals which were assessed.

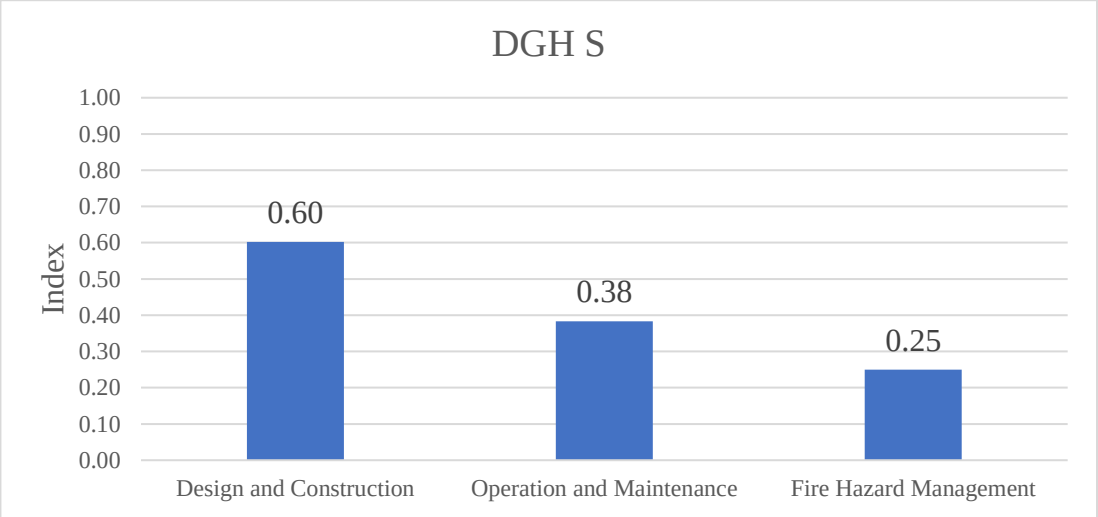

Figure 63: Assessment result summary of DGH S

7.2.2.4 Discussion of the Results

Even in the three government-owned hospitals, there were differences to be seen. These differences can be due to factors such as differences in location, hierarchy level of the hospital, and the knowledge and actions taken by the management division of the hospital.

Design and Construction

Each of the buildings assessed in the three hospitals were old buildings and therefore, there were many instances where the current building regulations were not met. The overall scores of the DC module for DH Q, BH U, and DGH S were 0.88, 0.67, and 0.60 respectively as shown in Figure 61, Figure 62, and Figure 63. The best performance was by DH Q and the poorest performance was by DGH S.

Considering exit doors, the requirements regarding door widths were met. However, most exit doors were not self-closing. All three buildings had two escape ways on each floor. Being multi-story buildings, the administration buildings of BH U and DGH S, both had two stairways on each floor. However, only the BH U building had a ramp. Neither of the buildings possessed smoke stop lobbies. Considering the submodule of means of escape, the scores for the hospitals DH Q, BHU, and DGH S were 0.80, 0.61, and 0.52 respectively.

Considering prevention of fire spreading between buildings, only DH Q had an adequate distance of over 15 m from other buildings. The assessed buildings in the other two hospitals only had a separation of 5-15 m. In all three hospitals, the kitchen and other areas of hazard were compartmentalized and separated from other areas of the hospital. All building material, roofing material, and floor finishes were of low combustibility. In the submodule of fire hazard prevention, DH Q received a score of 0.88, and BH U and DGH S both received a score of 0.81 each.

Considering the accessibility of the hospital to the fire brigade, the access way width of DH Q was sufficient. However, it was not the same for the other two hospitals. this could be attributed to the fact that these two hospitals are situated in more urban areas, thereby limiting the available space. The working space was similarly low for those two hospitals compared to DH Q. Considering the submodule of accessibility to fire

brigade, DH Q received the maximum score of 1.00, while BH U received a score of 0.50 and DGH S received a low score of 0.33.

Operation and Maintenance

The overall scores of the OM modules for DH Q, BH U, and DGH S were 0.48, 0.51, and 0.38 respectively as shown in Figure 61, Figure 62, and Figure 63. The highest performance in this module was by BH U and the poorest performance was by DGH S.

When considering the condition of the escape means in the hospitals, the access points to escape ways were obstructed at times with furniture such as cupboards and desks in both BH U and DGH S. The final exits in all three hospitals led to the hospital grounds. In both BH U and DGH S, the close proximity of the buildings has at times made the exit point near hazardous areas or narrow escape ways. The conditions of flooring in all three hospitals were good, with minimum possibility of slipping. There were no special provisions made for the safety of people with special needs during evacuation in any of the hospitals. Considering assembly points, none of the hospitals had a designated assembly point. Considering signage related to fire safety and evacuation, only BH U had emergency exit signs in the hospital. Other notices such as evacuation maps, assembly points signs, and fire action notices were not displayed in any of the three hospitals. Considering the submodule of means of escape, the scores for DH Q, BH U, and DGH S were 0.33, 0.42, and 0.33 respectively.

None of the three hospitals had fire detection and alarm systems installed. Both BH U and DGH S had speakers installed in the hospital, ensuring one-way emergency communication. In the submodule of fire detection and alarm systems, the score for DH Q was 0.00, and for BH U and DGH S, both scores were 0.08. There was a similar absence of sprinkler systems and fire blankets in each hospital. Considering fire extinguishers, only BH U had them sufficiently, but even so, they were not maintained sufficiently. DGH S and DH Q had a few extinguishers, which were insufficient for the whole hospital. Fire hose reels were present in some of the newer buildings in BH U and DGH S. Considering the submodule of active fire protection systems, the scores for DH Q, BH U, and DGH S were 0.06, 0.41, and 0.19 respectively.

Considering the prevention of fire hazards in the hospitals, most flammable materials in each hospital were kept under control and were secured. Similar to many government hospitals, the medical and general supply storages were somewhat tightly packed, making the possibility of a fire spreading in these areas somewhat high. However, the possibility of arson in the hospitals was well controlled with the employment of security officers. Waste management in each hospital was in a very good state, with the waste being separated at collection and stored in a secure location away from the main hospital buildings until collection. However, fire prevention in the kitchens is not as good, with none of the hospitals having fire suppression systems installed in the cooking ranges. The fuel storages in all three hospitals are in a similar state, especially considering the generator fuel storage. The fuel for the generator was stored inside the generator room in BH U and DGH S, providing a large quantity of fuel in case of a fire. when looking at electrical fire safety, only DH Q was in a good state. The other two hospitals had both experienced electrical fires in the past and were susceptible to overloading of electrical circuits. In the submodule of fire hazard prevention, the scores received were 0.88 for DH Q, 0.75 for BH U, and 0.55 for DGH S.

Considering access to fire brigade in the hospital, both BH U and DGH S had many vehicles parked in the hospital premises, which would provide obstructions to the fire brigade. Similarly, the vehicles parked adjacent to the access points of both the hospitals would mean more obstructions. This was not the case with DH Q. The local fire departments of each of the hospitals were familiar with the hospital premises. In the submodule firefighting, the scores for DH Q, BH U, and DGH S were 1.00, 0.67, and 0.83 respectively.

Fire Hazard Management

The overall scores for the hospitals DH Q, BH U and DGH S in the module FHM were 0.14, 0,.32, and 0.25 respectively as shown in Figure 61, Figure 62, and Figure 63. Overall, the fire hazard management was best in BH U out of the three hospitals, while the level of FHM was poorest in DH Q.

Both BH U and DGH S had disaster management plans for the hospitals, although they had not been updated in the last 2 years. Only BH U had a written fire action plan for the hospital, although that too was several years old. Each hospital had informal evacuation procedures for emergencies in the hospital. None of the hospitals had a designated emergency response team. In the submodule of disaster planning, DH Q received a score of 0.07, BH U received a score of 0.36 and DGH S received a score of 0.25.

A majority of the staff in BH U had received instructions in fire prevention and fire protection (usage of fire extinguishing equipment, fire drills, and patient evacuation). A lesser portion of the staff at DGH S had received instructions as well. However, the staff at DH Q had only a minimal level of knowledge regarding fire protection. Although fire safety drills and training had been carried out at BH U and DGH S, the exercises have not been held as regularly as annually, which is usually recommended by the fire safety authorities. A majority of the staff in each hospital possessed knowledge regarding contacting the local fire service department during an emergency. None of the hospitals had a fire commander, and unlike any of the private hospitals, there was no designated person in charge of fire safety in any of the hospitals. Considering the submodule of staff training, the scores for DH Q, BH U, and DGH S were 0.14, 0.32, and 0.25 respectively.

None of the hospitals had annual inspections and testing done regarding fire safety equipment in the hospital and did not have servicing contracts for the equipment. Regular maintenance was done by the hospital supportive staff as necessary. In the submodule of inspection, maintenance, and testing, all three hospitals received a score of 0.25.

7.2.3 Comparison of the Assessment Results between Privately-Owned and Government-Owned Hospitals

Considering the FRAT scores of the six hospitals that were assessed, a clear difference is seen between privately-owned and government-owned hospitals, with privately-owned hospitals showing a better performance in overall fire risk management.

Looking at the module of Design and Construction, the differences in performances were not observed to be due to whether the hospital was privately-owned or government-owned. The scoring changed with factors such as the time of construction (fire regulations at the time of construction) and location (within a city or outside a city). For example, evacuation elements such as ramps were present in older multi-story buildings. As another example, accessibility of the buildings to other structures was better in hospitals that were located outside the city areas.

In the second module of Operation and Maintenance, overall, the privately-owned hospitals displayed a better performance than government-owned hospitals. Out of the six hospitals assessed, the two highest scores were from Hospitals B and C. Considering evacuation elements in each hospital, there was a consistent performance in each of the hospitals. However, considering designated assembly points, only Hospital C passed the check. A point of concern in the evacuation elements in two of the government-owned hospitals was the obstruction of escape ways such as staircases and corridors. Fire detection and alarm systems and active fire suppression systems were two areas where the government-owned hospitals lagged far behind privately-owned hospitals.

Considering fire hazard prevention activities, both types of hospitals performed similarly, with each hospital having safe and secured storage of flammable materials and good waste management and disposal systems. The risk of kitchen fire was higher in government-owned hospitals considering that none of the kitchens in the three hospitals had fire suppression systems installed in the cooking ranges. Out of the three privately-owned hospitals, two had fire suppression systems installed in the cooking ranges. Considering the risk of electric fires, two government-owned hospitals, and two privately-owned hospitals had experienced electric circuit overloading. Similarly, the same four hospitals pose problems for fire brigades to access the hospital due to vehicular parking on the premises.

Considering the third and final module of Fire Hazard Management, all three of the privately-owned hospitals performed better than the government-owned hospitals. in the area of disaster planning, the performance was best in Hospital C, BH U, and DGH S. However, staff training was an area where privately-owned hospitals showed better

performance. Unlike government-owned hospitals, privately-owned hospitals conducted staff training programs at regular periods (1 year or less) as a partial requirement for obtaining a “Fire License” from the local fire service departments. Similarly, maintenance and servicing of fire protection systems are also done in privately-owned hospitals.

7.3 Applicability of the FRAT

From the application, it was observed that almost all of the valid concerning points were covered by the FRAT tool. However, the application revealed a few key points that need to be incorporated into the tool.

The first point is looking at the possible danger that could arise from having medical gas disseminating points in close proximity to electrical outlets. In hospitals, medical gas is delivered to all parts of the hospitals from the manifold room (Medical gas disseminating point) through pipes. If electrical outlets are located too close to the gas disseminating points, the risk of fire will increase.

The next point is the strength of the parking areas of the fire brigade vehicles. For example, in Building 3 of Hospital B, it was noted that the parking area was directly above the wastewater treatment plant in the basement. If the slab above is not properly strengthened, bringing a fire brigade vehicle to the area would cause a hazard.

Another key point is controlling the danger of arson with patient rooms. Especially in private patient rooms, where security staff cannot directly observe the possibility of arson, other measures to identify the fire at early stages must be in place. For example, in Hospital C, an accidental fire due to a cooking incident (Toaster oven) was stopped at early stages due to the presence of heat detectors in the room.

Overall, the FRAT tool can be considered which can be used to assess a hospital in terms of the buildings separately as well as the hospital as a whole in various levels. By incorporating the key points mentioned above, the FRAT can be strengthened further.

8 Survey on Preparedness of Staff of Privately-Owned Hospitals in the Event of a Fire

8.1 Introduction

The preparedness of staff in private hospitals to face a fire hazard was studied through a structured questionnaire that was distributed in Hospitals A, B, and C. The questionnaire contained 20 questions. The questions looked at the demography of the staff, training provided in terms of fire safety and knowledge on evacuation procedures. The complete questionnaire has been attached in Appendix VII. A total of 66 responses were obtained.

8.2 Methodology

8.2.1 Structure of the Survey

The first part of the survey looked at the demography of the responders. The elements in the section included the job position of the responders, their gender, age category, number of years they had worked at the hospital, and previous work experience at hospitals.

The second section tested the preparedness of the responders in three different ways: their past experience with fire hazards in hospitals, training, and drills regarding fire hazards experienced in the current and previous workplaces and knowledge regarding the procedures that need to be followed during a fire hazard. The section considered activities regarding sounding the alarm, preliminary firefighting by the staff members, evacuation of self and patients and contacting the local fire service department. The final question was a self-evaluation of the responder's preparedness regarding fire hazards.

8.2.2 Choosing the Sample Set

8.2.2.1 Sampling Method

Hospitals have a large number of staff members, medical and non-medical, who have various types of duties and responsibilities. As a hospital has various areas with a high risk of fire, most staff members have a possibility of experiencing a fire hazard. Therefore, it is important that all staff members in a hospital possess a basic level of

preparedness for a fire hazard. Therefore, in this survey, a random sampling method was used, ensuring that staff members of all levels and various job titles were included in the survey.

8.2.2.2 Sample Size

The total population of permanent staff members in the three hospitals rounds off at 1500. Assuming a confidence level of 90% and a 10% margin of error, the ideal sample size was calculated.

For 90% confidence level

Z score = 1.65

$$\text{Sample Size} = \frac{\frac{z^2 \times p\,(1 - p)}{e^2}}{1 + \frac{z^2 \times p\,(1-p)}{e^2 N}} \quad (6)\ [205]$$

z = Z Score

p = Standard Deviation

e = Margin of Error

N = Population

The standard deviation was assumed as 0.5 in order to ensure the sample size was large enough.

Sample size = $[1.65^2 \times 0.5 \times (1–0.5) / 0.1^2] / [1 + (1.65^2 \times 0.5 \times (1–0.5) / 0.1^2 \times 1500)]$

= 65

8.3 Demography of the Responders

From the 66 responses obtained, 20 of the responses were from Hospital A staff, 30 from staff in Hospital B and 16 from staff in Hospital C. The responders included staff members from various sections of the hospital such as nursing staff, maintenance staff, security staff, office staff, store staff, laboratory staff, and supportive staff. The distribution of the responders according to their position can be seen in Figure 64. A higher population of respondees were female. Most of the responders were between

the ages of 20 and 49. These variations in gender and age can be seen in Figure 65 and Figure 66.

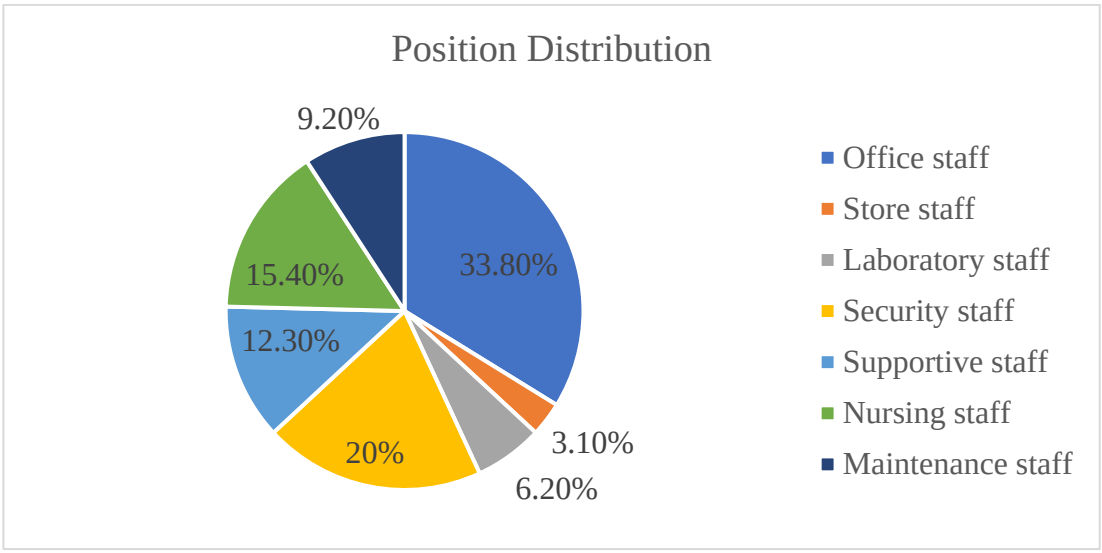

Figure 64: Job position distribution of responders

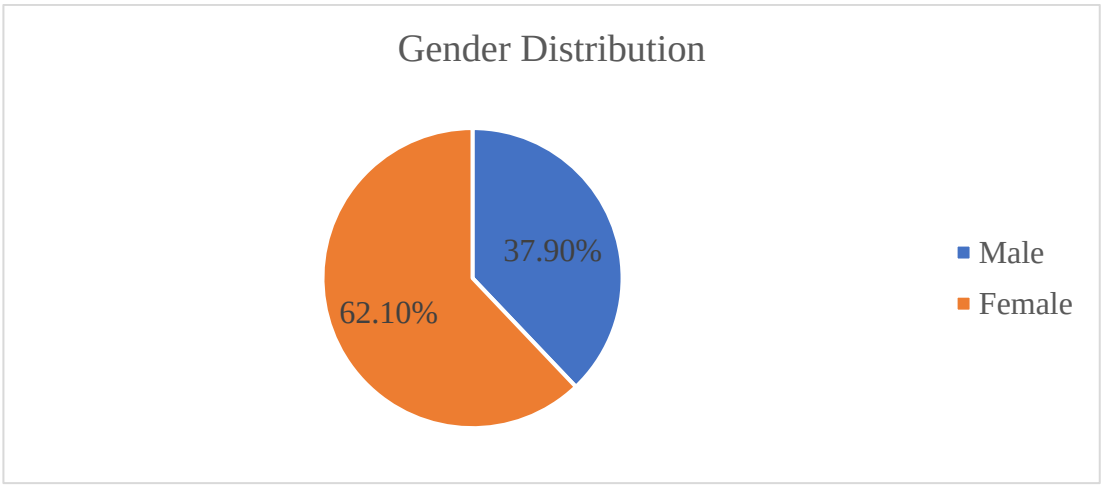

Figure 65: Gender distribution of responders

Looking at the number of years the responders had worked in the hospital, 21 responders had worked in the hospitals for less than 1 year while 14 had worked in the hospitals for over 10 years. This distribution is shown in Figure 67.

Out of the 66 responders, only 10 had previously worked in a hospital and from those 10, only 2 had worked in a governmental hospital.

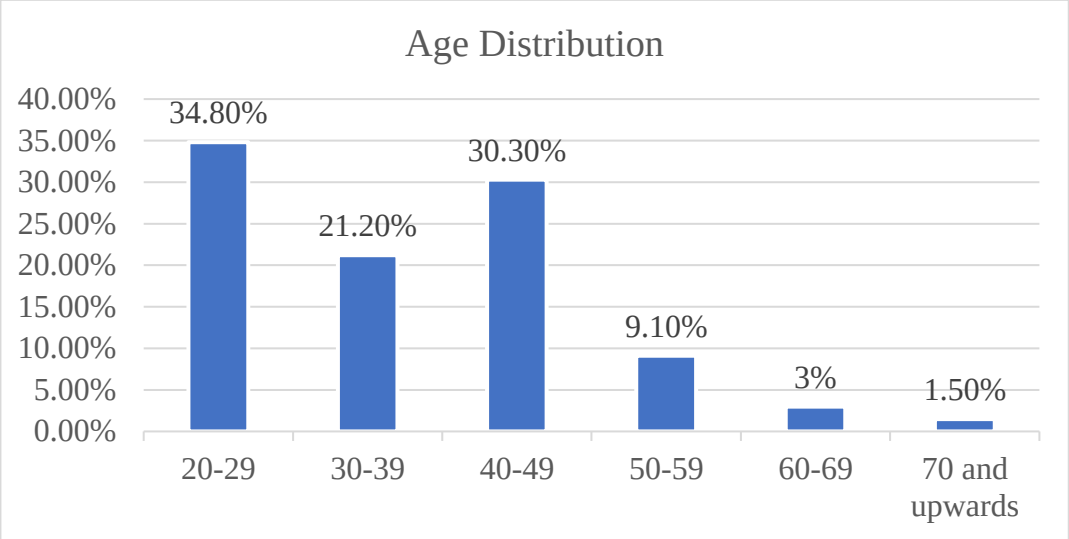

Figure 66: Age distribution of responders

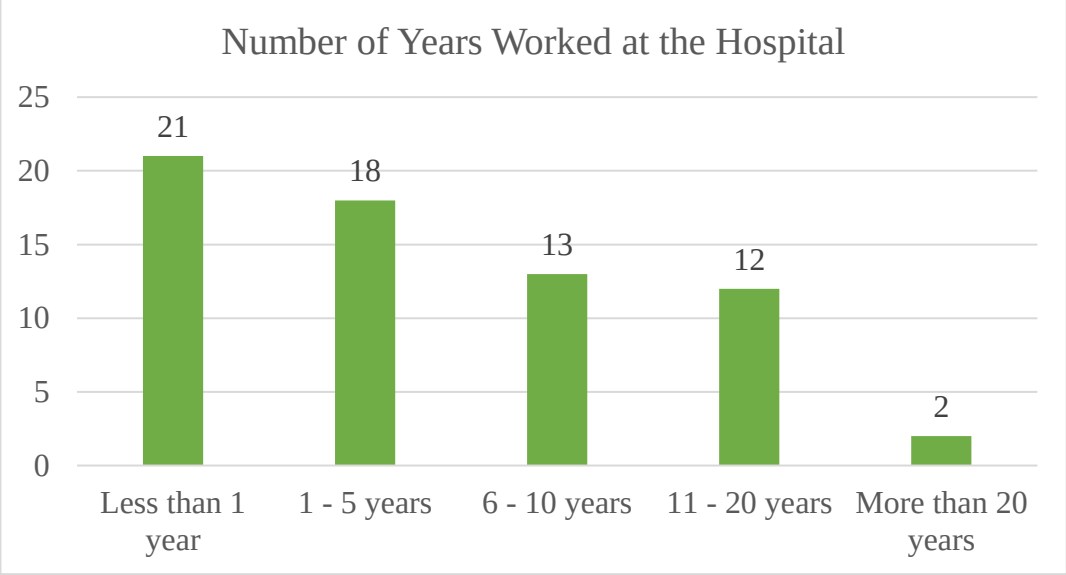

Figure 67: Number of years responders had worked in the current hospital

8.4 Results of the Questionnaire

Nine responders had experience with fires that had happened in the hospitals. All the fires were minor and extinguished quickly, avoiding the spread of fire. The fires included electric fires in the kitchen and electric panel in Hospital A, a fire in the generator caused by lightning and an electric fire in the basement in Hospital B, and an accidental fire in a patient room in Hospital C.

When looking at the fire training provided for the hospital staff, over 70% responded that they had received basic fire management training and a little over 60% had some kind of knowledge regarding the usage of fire protection appliances such as fire extinguishers. Over half of the responders had participated in fire safety drills. The statistics can be seen in Figure 68.

When looking at the collected data, it was observed that the staff who had received most of the training were from the hospitals' maintenance units and security units. During the interviews, many responders relayed that if a fire were to occur, they would quickly inform the maintenance and security personnel about the incident.

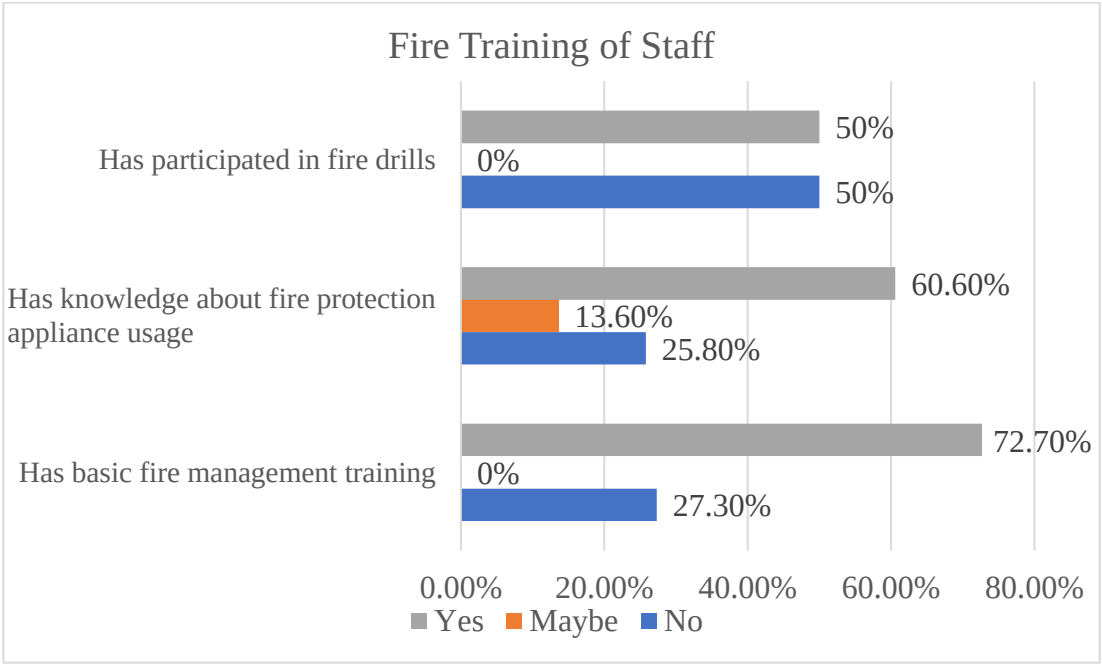

Figure 68: Fire safety related training of responders

From the interviews, it was observed that the responsibilities during a fire hazard varied for each kind of staff. For office staff, there were no other responsibilities other than evacuation if the fire occurred at another place. In all three hospitals, the office areas were on the upper floors, so this course of action would be best for these staff members. If the fire were to occur in the office areas, the staff must operate the manual call point and try to extinguish the fire.

Considering the nursing staff of the hospitals, they are in charge of safely evacuating the patients of wards along with their medical files and other necessary materials safely to the designated assembly point or another safe place.

The major responsibility during a fire would fall to the maintenance staff and security staff. They would be in charge of directing the evacuation of the other staff as well as patients and other hospital visitors. They will also be in charge of notifying the local fire service department.

In Hospital C, there was a designated Emergency Response Team. They have been given advanced training in fire safety and consist of maintenance unit staff, security staff, and kitchen staff.

Considering evacuation, staff members stated that an emergency evacuation without patients would take between 1 to 5 minutes, and with patients would take between 5 and 15 minutes. In reality, this would probably increase due to the traffic in stairways during an emergency.

In Hospitals A and B, where assembly points had not been designated, most of the responders declared that assembly would be done in the open area in front of the hospital buildings or the roadway. This would both put the evacuees in danger as well as cause trouble for the fire brigades who would come in. The staff in Hospital C all had knowledge of the assembly point of the hospital as it has been clearly designated with a sign.

When asked to self-evaluate their preparedness to face a fire hazard in their workplace on a scale of 1 to 5, with 5 being extremely prepared, the responders replied as can be seen in Figure 69. Over 68% of the responders have evaluated themselves as at least 75% prepared to successfully face a fire.

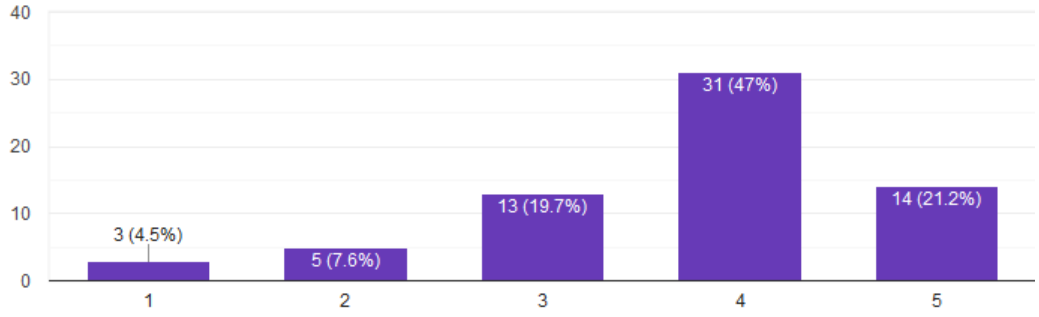

Figure 69: Self-evaluation of responders regarding their preparedness

9 Development of the Post-Disaster Activity List

9.1 Structure of the Activity List

The experience gained through the various visits done in hospitals throughout the study as well as peer discussions were used to develop a comprehensive and thorough list of activities to be done in a post-disaster scenario in a fire.

In this compilation, the categorization of activities was partially adopted from the Hospital Safety Index (HSI) Guide [23], where the major modules are structural safety, non-structural safety, and emergency and disaster management. Fire hazards can affect people and property. In hospitals, property can be divided into three as buildings and critical infrastructure systems, equipment, and materials. Post-disaster activities for a fire hazard will be needed for people and property both. There will also be management activities needed to be done to manage the aftermath of the disaster. The categorization for the activity list for the post-disaster fire situation was done as follows.

1. People — People
2. Buildings and critical infrastructure (CI) systems — Property
3. Equipment — Property
4. Hospital material stores — Property
5. Post-fire managerial and administrative work — Management

It was also deduced that the number and type of activities would differ according to the impact and magnitude of the fire. Therefore, the next part of the study included analyzing how to assign the activities according to the impact of the fire and the aspects of the hospital which could be affected by the fire.

9.2 Compilation of Post-Disaster Activities

As mentioned earlier, fires in hospitals can leave devastating results, and after the fire is extinguished, there remains a number of actions that must be taken, in order, to first, prevent damage that has occurred from spreading further. Next, action must be taken so that the recovery of the hospital is efficient and comprehensive, where the concept of Build Back Better (BBB) is fully adopted.

9.2.1 People

When considering the people in hospitals, it must be realized that there are various types of people within a hospital. They include hospital patients, patient' visitors, and hospital staff such as medical staff, supportive staff, administrative staff, and external service providers [10], [12]. After the fire, it is important that all persons who were in the fire-affected area are given a thorough medical examination, including those who do not show any physical trauma. This is because, in the occurrence of a fire, in addition to being burned, a person can be negatively impacted due to the bi-products of fire such as smoke and soot [206]. After the fire, it is important to confirm the safety of the affected area and do necessary investigation and cleanup before letting people come back into the buildings. Sometimes, the evacuated persons will have to be moved to another building in the area, or to another hospital entirely. In any case, there should be arranged a place of shelter where the evacuated persons can stay until a permanent arrangement is made. As there could be a need for hospital patients and victims of the fire to be transferred to another hospital, transportation systems such as ambulances from the hospital should be prepared to be used if necessary.

During the initial medical examination, the affected persons will be identified. After providing emergency medical care, the victims of the fire must be admitted for further medical care. This could be done in the same hospital if possible, or in the next nearest hospital that can provide sufficient medical care. Similarly, any hospital patients who were evacuated during the fire should be similarly transferred to another area of the hospital, which was unaffected by the fire, or to the nearest hospital which can fulfill the medical requirements of the patients.

A catastrophic disaster can cause a situation where there will be people missing after the fire. In this case, first, a list of all people missing must be compiled by the hospital administration staff in cooperation with relevant authorities such as the police force and the firefighting department. Search operations for the missing persons should be arranged and conducted.

In some cases, victims may be found deceased. In this case, usually, most countries' police force or other relevant authorities have a process of action that must be taken.

In general, the following work must be done; the deceased victims should be identified, if possible, and after possible investigation on the site of the fire has been concluded, the deceased victim must then be transferred to an examination area to perform an autopsy. After the investigative and medical work has been concluded, the body may be released to the deceased's family [207].

Another action that must be taken is to recruit staff in order to replace any staff member who might have been affected by the fire and will be needing some recuperating time [23].

Finally, there is some long-term recovery-related work that needs to be done, for the people who were affected by the fire as well as for their families. In addition to suffering from injuries and loss of property, they may also suffer from loss of income revenue due to the losses incurred. Therefore, it is necessary that the hospital provide compensation to the victim or the victim's family. For the fire-impacted persons, who are seeking to claim from personal insurance policies, the hospital should be efficient in arranging the necessary documentation for the insurance companies. Finally, as to ascertain the wellness of the affected populations' emotional stability, the hospital should arrange and offer counseling services for the people.

9.2.2 Buildings and Critical Infrastructure Systems

As mentioned before, it is unwise to enter the fire-affected buildings immediately after the fire has been extinguished. The buildings that were affected directly by the fire as well as indirectly through the byproducts of fire like smoke should be given an initial check to confirm whether the area is safe to be entered. This should be done by a trained professional such as a firefighter. The critical infrastructure systems in the affected area should also be checked to ensure that the extinguished fire would not cause cascading disasters through the systems. These systems will include electrical, water supply, medical gas, fuel supply, heating, ventilation, and air conditioning, waste management, and elevator systems. Another action that must be taken is to clear the paths and routes within the hospital that may have been blocked during the fire, so that patient translocations that are needed can be done easily and safely.

In case of severe damage, the next step is to contact the insurance agency of the hospital. This step is to be taken if the hospital has been insured. The damages in the affected area must be assessed by the responsible authorities such as the insurance agents, firefighters, and police officers. The assessed damages must thus be documented. After the assessment and documentation have been completed by all parties responsible, the affected area should be thoroughly cleaned up, which will include the toxic products that will have been left by the fire, like toxic gases, smoke, and soot.

Before the fire-affected area of the hospital can rebegin to operate, the necessary retrofitting and reparation of damages can be done. This should be planned methodically and thoroughly.

During the fire, fire detectors and fire alarms, firefighting equipment such as sprinkler systems and fire hose reels and portable fire extinguishers could have been used. Afterward, the hospital should take care to replace any fire extinguishers used. Also, all the systems including fire detection and alarms and sprinkler systems should be assessed and any damage incurred should be repaired as soon as possible.

9.2.3 Hospital Equipment

Hospitals have many kinds of equipment, including medical equipment, laboratory equipment, and other equipment such as kitchen equipment. If the fire-affected area has any type of equipment present, certain steps should be taken. First, equipment in the area should be checked to see if any damage has been incurred during the fire. If so, the hospital must contact the insurance agency if the equipment has been insured.

The damage to the equipment should be assessed and documented and necessary reparations or replacements of the equipment should be done.

9.2.4 Hospital Material Stores

Hospitals are required to have storage spaces for various items. Usually, there are general supply stores, medical stores, surgical equipment stores, blood banks, and other miscellaneous item stores (recycle items storage, kitchen supply storage, etc.). In the occurrence of these storage spaces being affected by the fire, the following actions must be taken. An initial check must be carried out to assess if any serious

damage has been caused by the fire. If the damaged store items have been insured, the insurance agency must be contacted and notified. Then the damage should be assessed and documented and finally, the stores must be restocked if needed.

9.2.5 Post-Fire Managerial and Administrative Work

It is important, that after any type of disaster, the administration takes action so that the institution is not only restored to its pre-disaster status but improved even further. Here, the paper discusses the summary of the actions that the hospital's administrative division should take so that in the future, the hospital's resilience is increased through principles of Build Back Better (BBB).

As soon as possible after the fire is extinguished, the fire-affected areas must be secured until the investigative and restorative work is completed. The police force must be contacted, and the cause of fire should be investigated.

Working with media institutions is an important part of post-disaster recovery. In order to prevent the propagation of misinformation and unnecessary panic, it is important that the administration of the hospital prepare and present a statement regarding the fire disaster to the media at the earliest possible time.

Another important factor is the continuity of the administrative work after the fire. In case the fire caused administrative office facilities to be affected, temporary office facilities should be arranged until restorative work is completed.

A vital element of post-disaster activities is the Disaster Recovery Plan (DRP). The administration should prepare a customized DRP, put it into operation, and monitor and evaluate the outcomes. After a disaster, institutions have to be prepared to manage donations and other kinds of funding that will come through to the institution. The management of the funding flow should also be included in the disaster recovery plan.

The next significant item of action is the updating of the hospital disaster management plan. In order to BBB and increase resilience, it is important that the disaster management plan is updated from the "Lessons Learnt" from the past disasters that occurred. It is therefore important to review the actions of the hospital staff during the fire and analyze the weaknesses of the current action plan. Thereby, the hospital disaster management plan can be reviewed and modified to better suit the institution.

9.3 Summarization of the Proposed Activity List

The developed list of proposed activities to be conducted after a fire disaster occurs in a hospital is has been summarized in tabulated form in Table 22

Table 22: Post-disaster activities to be conducted in a hospital after a fire

People	Building and Critical Infrastructure Systems
A 1. Provide medical attention to all persons who were in the affected area 2. Provide a shelter space for all persons who were evacuated from the affected area **B** 3. Arrange transportation systems such as ambulances in preparation to transfer patients **C** 4. Admit the victims affected by the disaster a. To the same hospital if suitable b. To the next hospital which fulfills the medical requirements of the patients **D** 5. Transfer the evacuated patients a. To an unaffected part of the hospital if suitable b. To the nearest hospital which fulfills the medical requirements of the patients **E** 6. Provide compensation to victims affected by the fire or the victims' families 7. Provide validating documentation for victims claiming personal insurance 8. Arrange counseling for disaster victims **F** 9. Identify missing persons 10. Arrange search operations for missing persons **G** 11. When a victim is found diseased a. Identify victims (If possible, through visual inspection) b. Conduct an onsite examination of the body c. Transfer the body to an examination area d. Perform autopsy e. Release body to victims' families	**I** 1. Conduct initial check by trained professionals to confirm whether the area is safe to enter 2. Conduct a check of infrastructure systems to confirm the operational capability a. Electrical systems b. Water supply systems c. Medical gas supply d. Fuel supply e. HVAC system f. Waste management systems g. Elevator systems 3. Clearing paths and routes within the hospital **J** 4. Contact hospital insurance company 5. Assess damages and document the damages **K** 6. Clean area affected by the fire and dispose of toxic products of the fire **L** 7. Retrofitting and reparation of damages in the affected area **M** 8. Restock the equipment used for fire fighting

H 12. Mobilization and recruitment of new hospital staff	
Hospital Equipment	**Hospital Material Stores**
N 1. Initial check to see whether the equipment is damaged or safe to use **O** 2. Contact insurance company 3. Assess the damage of the equipment 4. Reparation or replacement of damaged equipment	**P** 1. Contact insurance company 2. Assessment of damage 3. Restock stores if needed
Post-Fire Managerial and Administrative Work	
1. Secure the areas affected by the fire until restoration is completed 2. Contact Police and start the investigation of the fire and its cause of origin 3. Prepare and present a statement regarding the disaster event to the media 4. Provide temporary office facilities in case administrative buildings are affected 5. Disaster Recovery Plan a. Prepare plan b. Operate the plan c. Monitor and evaluate outcomes 6. Hospital Disaster Management Plan a. Review hospital actions during the fire b. Deduce weaknesses in the current plan of action c. Review the plan of action during a disaster and modify 7. Manage funding and donations given for reparations	

Although the compiled list of activities is vast and comprehensive, it must be realized that not all of the activities will be needed to be done in each and every occurrence of a fire hazard. As we can see in Figure 70, the area affected by fire directly depends on the time taken to stop the fire. If the time taken to extinguish the fire increases, the fire can spread from point of origin to the complete room and adjacent rooms to the other floors in the building and then to other buildings in the vicinity. With the level of impact, the impacted aspects of the healthcare institution can vary.

A fire can be extinguished almost immediately after it starts, resulting in no losses being incurred on any people, buildings, or equipment. There can be some instances, where no people are harmed, but the equipment is severely damaged. There can also be instances where a large portion of the hospital is damaged, meaning there are losses incurred in all aspects of the hospital.

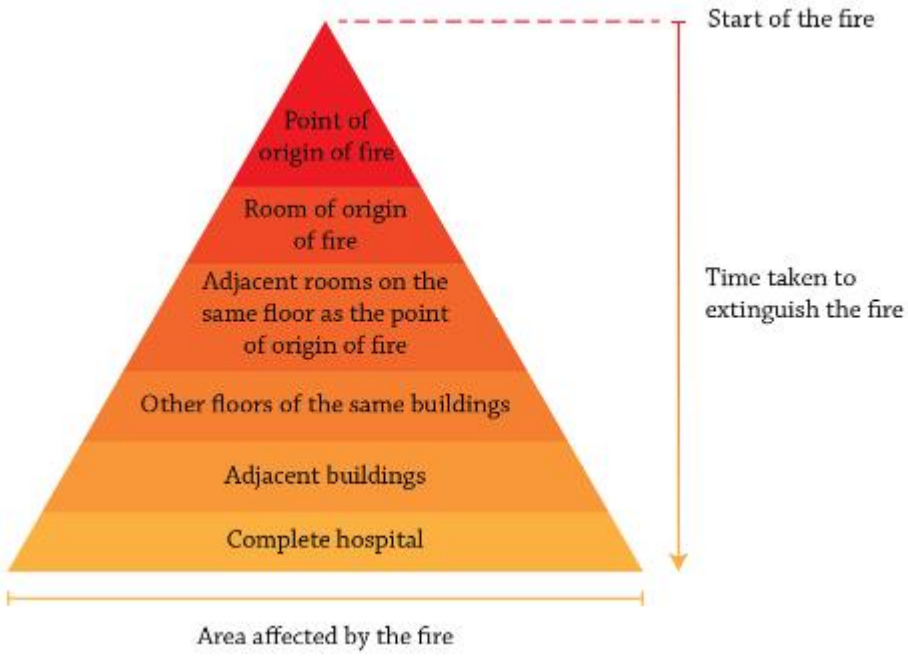

Figure 70: Variation of the impact of fire with time

In Figure 71, Figure 73, Figure 74, and Figure 72, it has been identified how the activities needed to be done after varying levels of impacts of fire can be chosen from the list that has been compiled.

According to the impact level of the fire, people could be affected on different levels. A minor fire could bring zero or minimal level of harm to people. With the escalation of fire impact, the harm to people could change from minor injuries to serious injuries and death. If hospital patients are evacuated, there must be a process to return the patients to a hospital facility. Again, if the hospital staff is affected or injured by the fire, there must be a process to recruit replacement staff.

Similarly, the impact level of fire on hospital property including buildings and critical infrastructure systems, hospital equipment, and material stores will determine the actions which need to be taken as shown by the activity sequences in Figure 73, Figure 74, and Figure 72. For property, there are actions that must be taken for any level of fire in the affected area. If the property experienced any significant damage, there must

be more actions taken. If any fire suppression equipment were used, they must also be inspected and serviced or refilled.

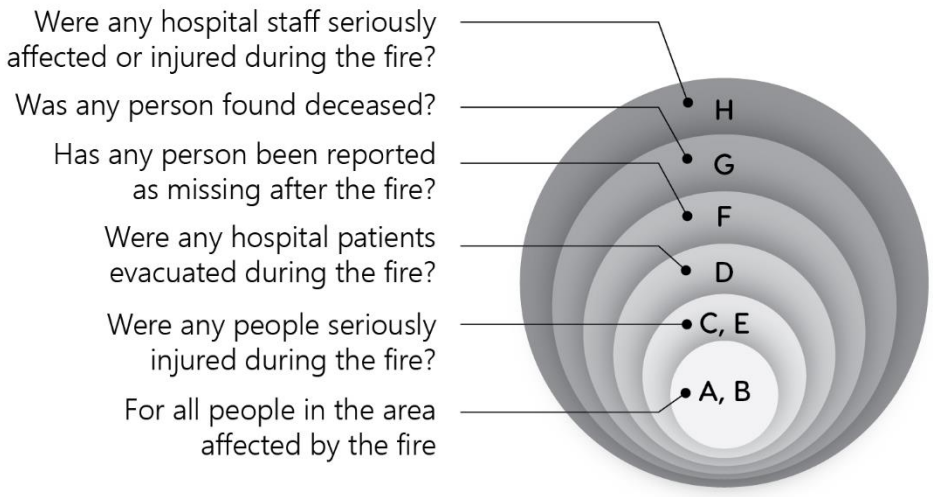

Figure 71: Activity categorization according to the impact of fire on people

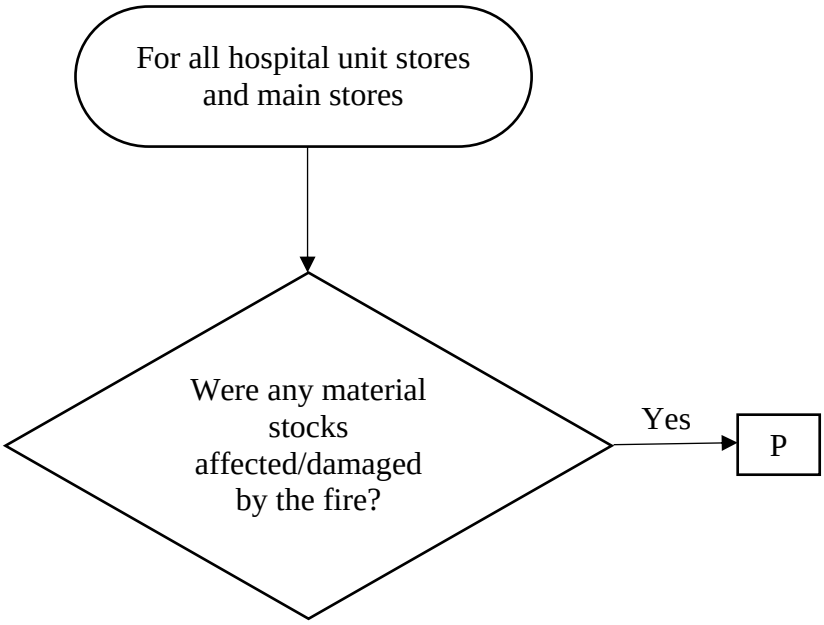

Figure 72: Activity sequence for material stores in the fire-affected area

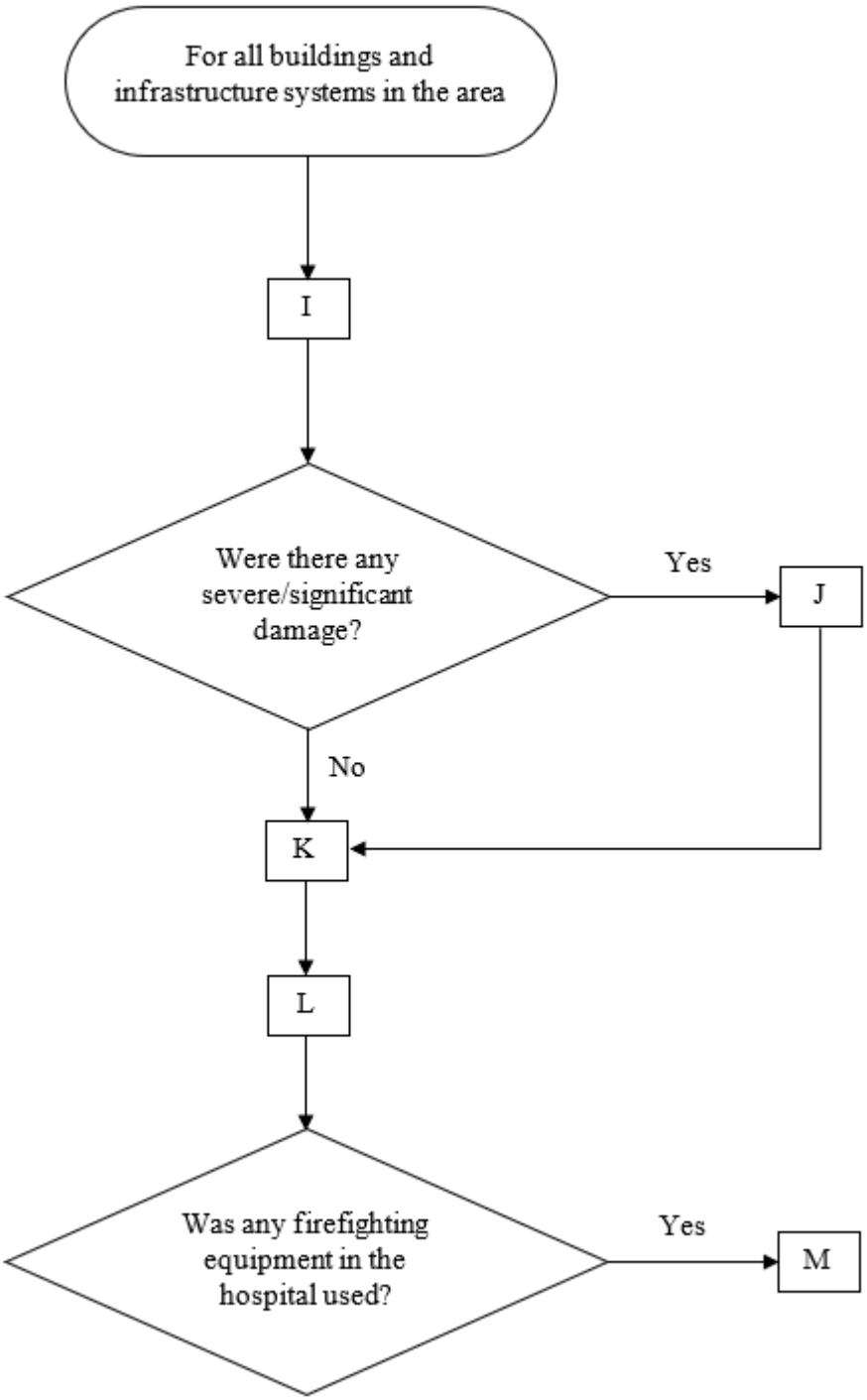

Figure 73: Activity sequence for buildings and critical infrastructure in the fire-affected area

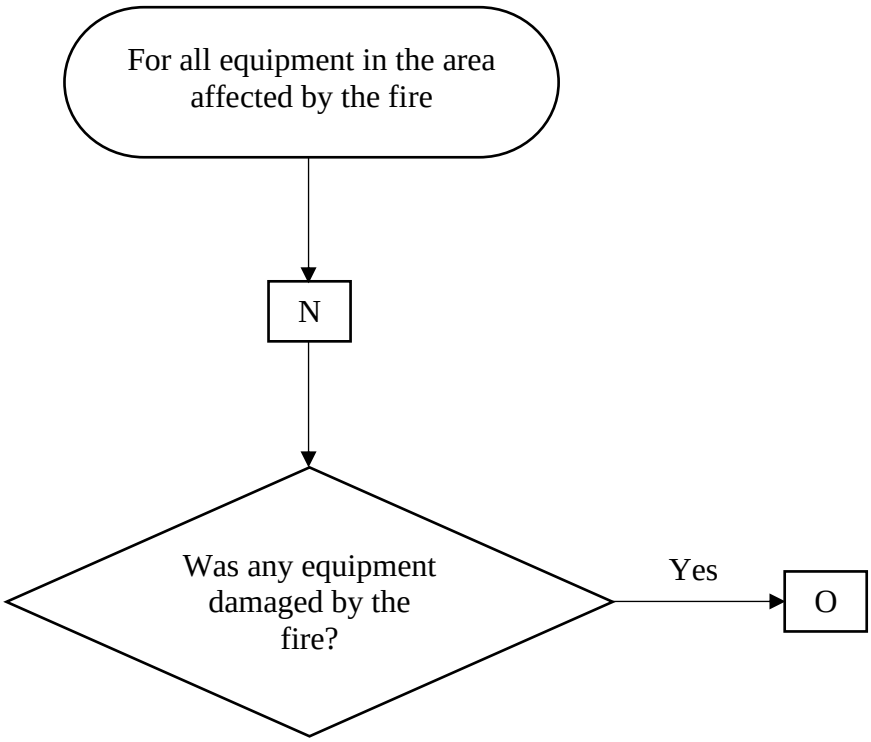

Figure 74: Activity sequence for equipment in the fire-affected area

9.4 Validation of the Activity List

9.4.1 Method of Validation

The developed list of activities was validated with expert opinion, which is a suitable method for content validation. These experts had experience and expertise in the fields of healthcare, disaster risk reduction, construction industry, and fire safety engineering. They represent both the industrial and academic sectors. The sample size of the experts was 31. The distribution of the fields of expertise is given in Figure 75.

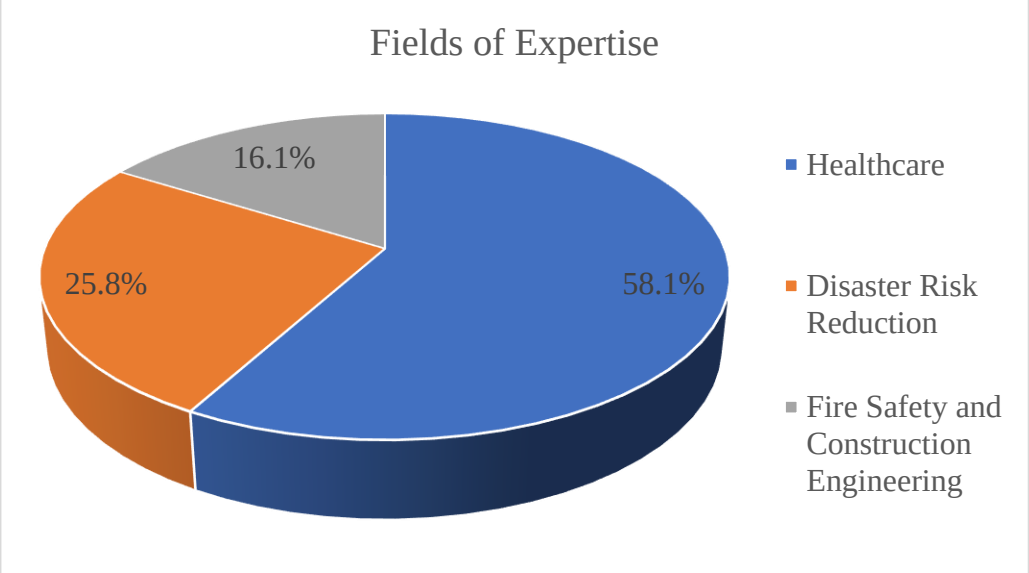

Figure 75: Fields of expertise of the experts

The experts were requested to score each activity in the criteria list with a score of 1 to 5, where the scoring systems represented various levels of agreement as given below.

1 – Strongly disagree

2 – Disagree

3 – Undecided

4 – Agree

5 – Strongly agree

9.4.2 Reliability of the Data

The reliability of the data was determined and verified using a commonly used reliability coefficient: Cronbach alpha. When the Cronbach alpha is less than 0.3, the data is not suitable for further analysis as the reliability of data is too low. The data can be considered as suitable for further analysis when the Cronbach alpha is greater than 0.7, as the reliability is high.

The Cronbach alpha was determined using the IBM SPSS 26 software. The equation for the Cronbach alpha is given below.

$$\alpha = \frac{N\,\bar{c}}{\bar{v} + (N - 1)\,\bar{c}} \tag{7}$$

α = Cronbach alpha

N = Number of items

$\bar{c}$ = Average inter-item covariance among the items

$\bar{v}$ = Average variance

The computed value for the Cronbach alpha was 0.983. this meant that the collected data set can be used for further analysis.

Table 23: Results obtained from IBM SPSS 26 software

Reliability Statistics	
Cronbach Alpha	N of Items
0.983	42

9.4.3 Results of Validation Process

The responses for each post-disaster activity category were developed into box-and-whisker diagrams, as seen in Figure 76, Figure 77, Figure 78, Figure 79, and Figure 80. The activity numbers on each chart correspond to the activity numbers in Table 22 for each category. The outliers are denoted by dots (•). The quartiles are enclosed by the box and the whiskers show the values that are not outliers. The average level of agreement for each activity is denoted by ×.

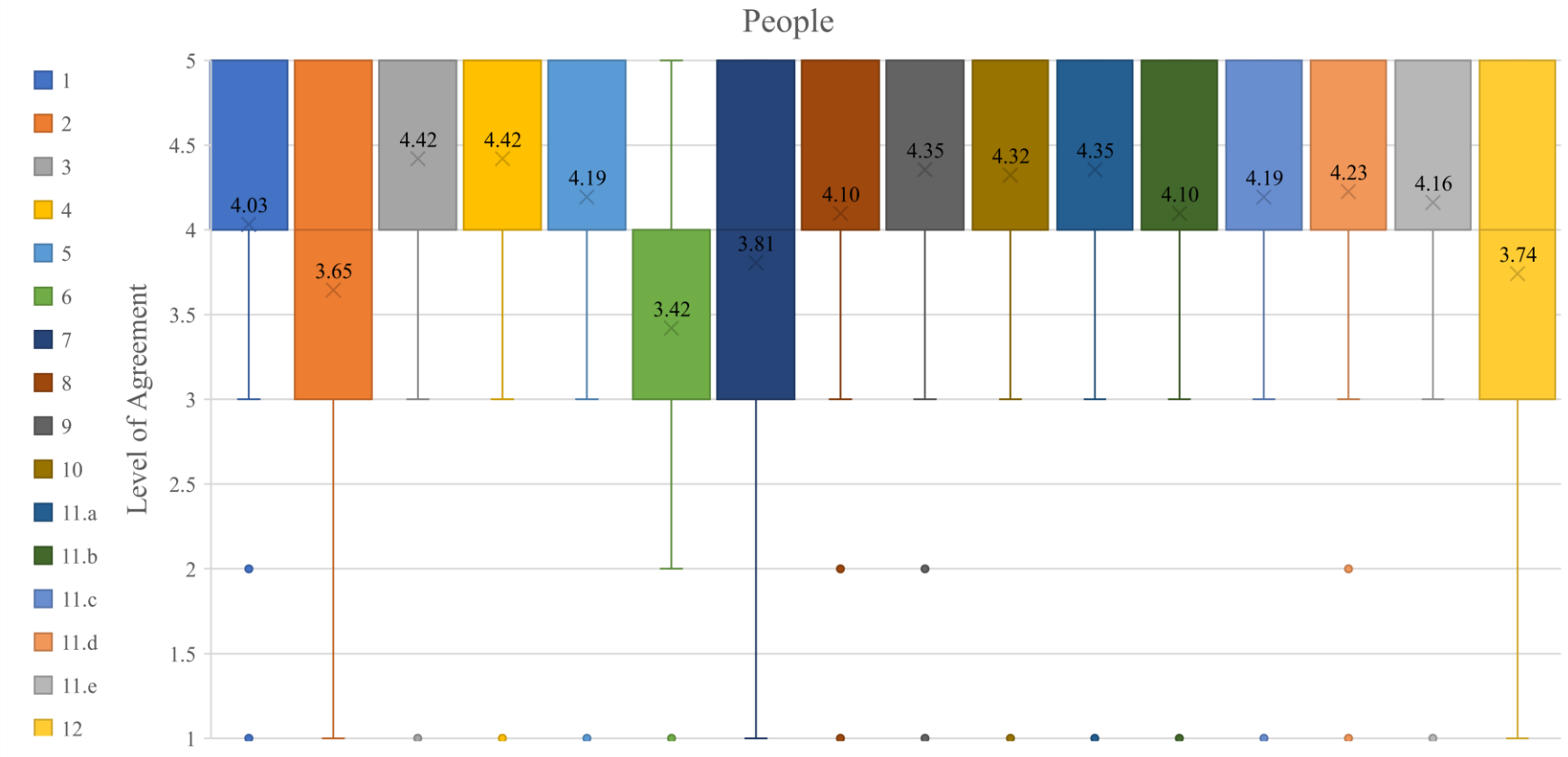

Figure 76: Level of agreement for post-disaster activities for people

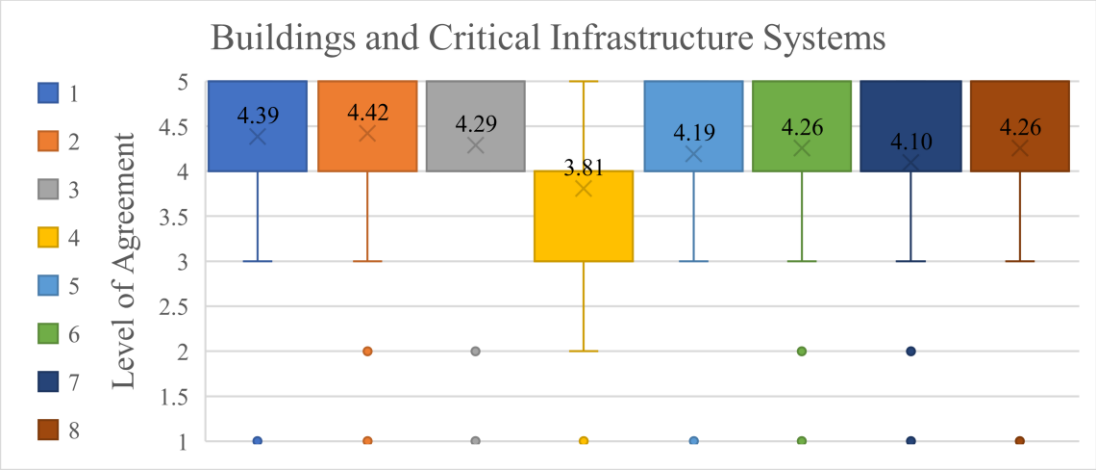

Figure 77: Level of agreement for post-disaster activities for buildings and critical infrastructure

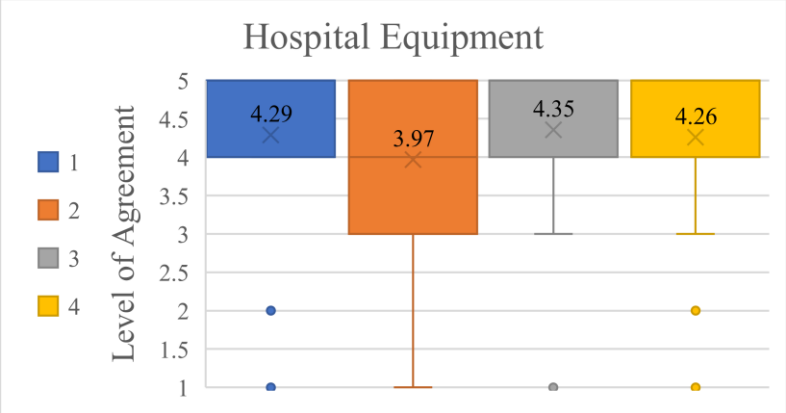

Figure 78: Level of agreement for post-disaster activities for hospital equipment

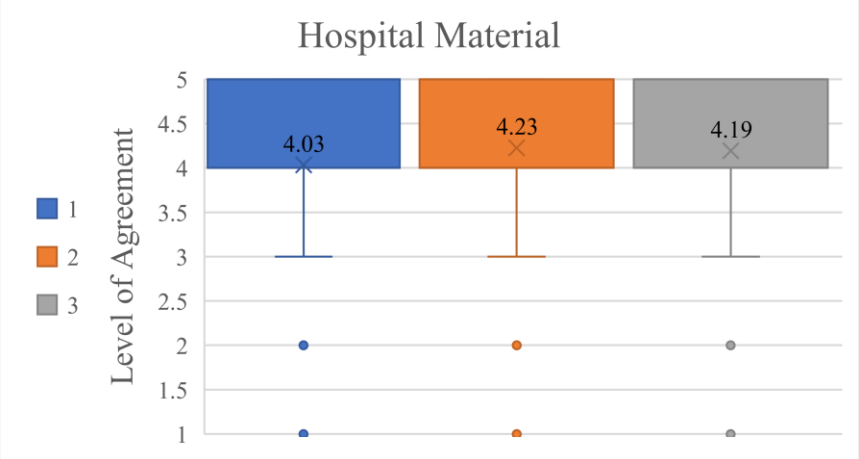

Figure 79: Level of agreement for post-disaster activities for hospital materials

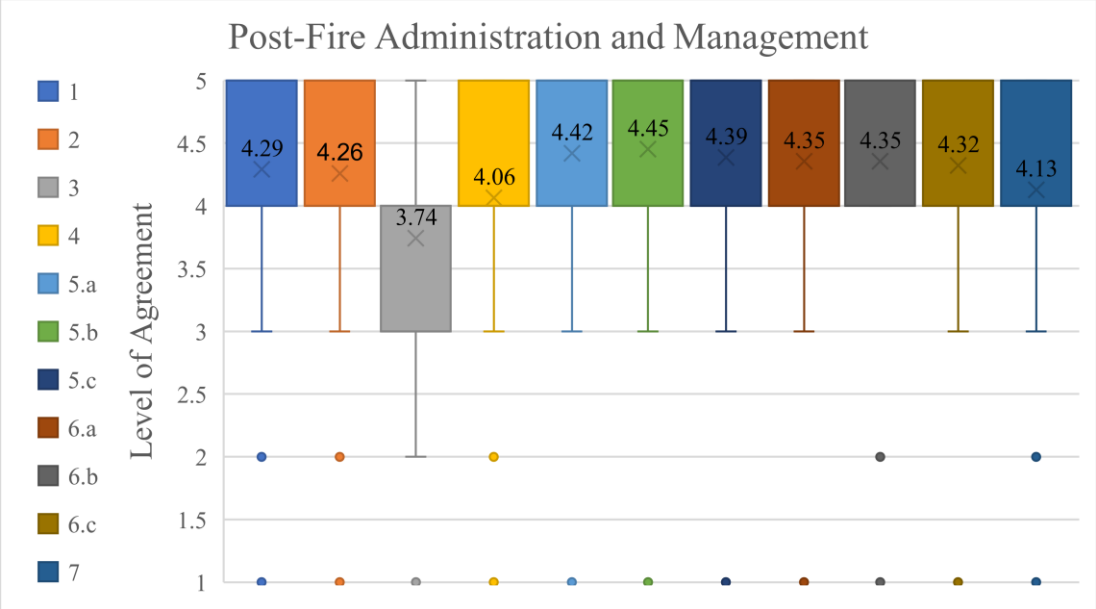

Figure 80: Level of agreement for post-disaster activities for post-disaster administrative and managerial work

9.4.4 Discussion

The experts' responses show that all activities on the list have received an average level of agreement above 3.0 (Above average). Thus, each activity in the activity list has been admitted as valid for the aftermath of a fire hazard in a hospital, according to the impact level and impacted elements. Therefore, there is no need to eliminate any activity from the list.

Most of the activities were given an average level of agreement falling between 4 and 5, meaning a high level of agreement. However, for some activities, the level of agreement was somewhat lower, falling between 3 and 4. In activities regarding people, as seen in Figure 76, the lowest level of agreement was 3.42, for the action of providing compensation for victims of fire. The other actions with a lower level of agreement were provision of shelter for evacuated people (3.65), provision of validating documentation for insurance claims (3.81), and recruitment of replacement hospital staff (3.74).

In the activity list regarding buildings and critical infrastructure, only the action of contacting the hospital insurance company received a lower level of agreement at 3.81, as seen in Figure 77. This response could be due to the fact that government-owned hospitals in Sri Lanka do not usually have insurance for buildings. However, most private-owned hospitals in Sri Lanka as well as hospitals in developed countries have hospital insurance, meaning this action would be needed in most cases. A similarly lower level of agreement (3.97) was received for the action of contacting hospital insurance company in case hospital equipment is affected by fire, as shown in Figure 74. In the case of hospital materials, all three activities received levels of agreement above 4.00, according to Figure 79. Considering post-disaster administrative and management work, as seen in Figure 80, the action of presenting a media statement regarding the fire hazard received a lower level of agreement at 3.74.

This list of post-disaster activities for fire hazards in hospitals has been developed as a tool for administrative and planning unit officials in hospitals. This should be edited by these officials by selecting the applicable activities according to the impacted elements in the hospital and the impact level of the fire.

10 Conclusions and Recommendations

10.1 Concluding Remarks

Fire can start at an insignificant size and develop quickly into an uncontrollable hazard that will cause disasters of large proportions. In a hospital, where there are a highly vulnerable population and expensive material and equipment, it is extremely important that the risk of fire is minimized to the fullest extent. The reduction of fire risk should be done by minimizing the exposure to fire and maximizing the preparedness of the hospital and its staff to face fire hazards.

To reduce the exposure of the hospital to fire, first the major causes of fire should be identified. When looking at hospital fires in general, past studies have shown that a majority of fires have occurred in kitchen areas. However, when the focus is shifted to major fire causing high levels of disasters, it has been observed that electric fires were mainly seen. When looking at the preliminary and in-depth work done in this study, again electric fires have been observed to be the commonest type of fire Sri Lankan hospitals have experienced in the past. This has been observed to be the case in both governmental and private-owned hospitals. Therefore, in fire hazard prevention, these areas of exposure should be thoroughly secured.

During a fire, it is essential that the support of the local fire brigade is received at the earliest. This requires that the fire brigade arrives very quickly upon being notified of the fire. However, if the location of the fire is at a significant distance from the fire service department, the response time of the fire brigade could be long. Another factor that would affect the response time of the fire brigade would be the time of the fire, as road traffic could pose a problem.

One of the main objectives of this study was to develop a Fire Risk Assessment Tool which can be used to assess the level of fire risk in a hospital in a structured manner and thereby the weaknesses can be identified and rectified. The FRAT identified three areas of assessment: design and construction, operation and maintenance, and fire hazard management. This identifies that fire risk management should begin during the designing of the building and should continue throughout the operating period of the hospitals.

When analyzing the data collected from the studies done at both governmental and private-owned hospitals during the research study, a few key points were observed. In both types of hospitals, the older buildings showed low levels of performance in design and construction. This can be attributed to the lack of regulations regarding fire safety during the construction periods of these buildings. For example, having only 1 exit stairway and lack of smoke stop lobbies from multi-story buildings was seen in these older buildings. The opposite was seen in buildings built more recently, as they showed high levels of performance in design and construction. This is because the current building regulation in Sri Lanka requires the building designs to be passed through the fire service department to be approved before construction can begin.

Again, looking at the operation and maintenance module as well as the fire hazard management module, it can be stated that the private-owned hospitals assessed were in better conditions compared to all the assessed government hospitals. This can be attributed to the "Fire License" private-owned hospitals are required to obtain annually to gain from the fire service department in order to continue operation of the hospital. This necessity has promoted the installation of fire protection systems in the hospital such as fire extinguishers, water hose reels, and alarm systems, annual maintenance and testing of fire protection systems by external contractors and annual fire training and fire drills done by the local fire service department or the Special Task Force of the country. The same actions were either not done or only done sparsely in governmental hospitals.

Being prepared for post-disaster actions is an important part of fire risk management. Fire in a hospital can affect various elements, including people (Staff, patients, hospital visitors), buildings, critical infrastructure, hospital equipment, and management. Therefore, it is vital that the hospital administration is prepared for a post-disaster situation as well as pre-disaster and disaster situations. This preparedness can be increased by previously identifying activities that will probably be needed during a situation so that the post-disaster planning can be done quickly and efficiently.

10.2 Recommendations

The following recommendations are made for hospitals in order to increase their fire risk preparedness.

- The following areas in a hospital have been identified as areas of high risk.
    - Electric panel room
    - Kitchen
    - Generator room
    - Manifold room
    - Laboratory areas
    - Incinerator
    - Medical equipment and drug storage rooms

  These areas should be compartmentalized, and the rooms should be supplied with fire blankets and fire extinguishers. The areas should be secured and in good condition. Any fuel storage in these areas should be secured and placed away from flammable material.

- Automatic smoke/heat detectors and alarm systems should be installed in the hospital, especially in areas with a high number of people present.
- A fire risk assessment or a complete hospital risk assessment should be conducted regularly at least every two years.
- Hospital should have a designated Fire Commander, who will be in charge of fire safety activities in the hospital.
- Annual testing and maintenance of fire protection systems must be done and items such as fire extinguishers should be tested and updated annually.
- Hospital should prepare a Hospital Disaster Management Plan which should include a Fire Action Plan and Emergency Evacuation Procedures. The HDMP should be updated regularly and practiced by all hospital staff. The plan should have the responsibilities of staff designated for an emergency.
- At least annual basic fire safety training and fire drills should be conducted for the staff. If the training sessions cannot cover the entire staff, at least one person from each unit or department in the hospital should be included in the training.

- The hospital should have an Emergency Response Team designated. Usually, this team will consist of staff members who have the least responsibilities of hospital patients.
- Hospital should have a designated primary assembly point as well as a secondary assembly point. These points should be marked by signs and should be known to all hospital staff. The assembly points should be away from places where the fire brigade vehicles will need to access to enter the hospital buildings.
- Signs for emergency exits and stairways and evacuation maps must be provided on each floor of the hospital buildings in visible locations.
- Hospital staff should be aware of the procedure of sounding the alarm during a fire, especially in areas holding critical-level patients and evacuating patients safely to the assembly points during an emergency. It is recommended that this is practiced during fire drills.
- Hospital should have procedures in place to follow regarding contacting the fire service department in the case of a fire in the hospital. If the hospital has a designated person or person in charge of notifying the fire service department, it is recommended that this is made aware to all the hospital staff.
- Waste management should be handled carefully. Waster should be separated at collection and regular disposal must be done. Waste storage rooms should be secured and in low fire risk conditions.
- Hospital administration should have insurance that covers the hospital and its assets, hospital patients, and hospital staff.

10.3 Future Work

This research study can be extended in several areas. One of the main outputs of the study is the FRAT tool. This tool can be utilized by administrators in the health care field in order to assess the current level of risk in a healthcare facility with regards to fire. Through filling out the FRAT forms, the administrators should also be able to identify the weaknesses in the organization by reviewing the criteria that gained lower scores. The usage of the FRAt tool will not directly provide information on actions to improve the risk management. One area where more work can be done for this study is identifying actions that can be proposed to reduce the weaknesses identified by the FRAT tool.

In this version of the FRAT tool, each criteria is given an equal weightage in calculating the overall fire risk level. However, realistically each criteria will have a different level of importance contributing to the risk management level of the hospital. This is another area where the study can be extended, by identifying suitable weightages for each criteria in the FRAT tool.

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Appendix I : Assessment of Hospital A

Table 24: Hospital A - Design and construction assessment

Means of Escape				
Criteria	Score			
	Building 1	Building 2	Building 3	Building 4
Exit door				
Clear width of doors is 1100mm-1250mm	1	1	1	1
Exit doors open in direction of escape	1	0.5	0	0
Exit doors are self-closing	1	0	0	0
Exit ways				
Number of exit ways from hospital wards	1	1	0	0
Exit stairways				
Number of stairways each floor (Can include ramps, external staircases)	1	1	0	NA
Provision of ramps (Applicable if patients stay in the building)	1	NA	NA	NA
Handrails for stairways are provided	1	1	1	NA
Access for wheelchairs or trolleys in corridors and stairways				
Access width is greater than 950 mm	1	0.5	0.5	NA
Smoke stop lobby (If there are 2 or more floors)				
Provision of smoke stop lobby in each floor	0	0	0	NA
Impedance to escape movements	0	0	0	NA
Pressurized ventilation	0	0	0	NA
Total	8	5	2.5	1
Index	0.73	0.50	0.25	0.25
Fire Hazard Prevention				
Criteria	Score			
	Building 1	Building 2	Building 3	Building 4
General				
Proximity to buildings	0	0	0	0
Kitchen area is separated from other areas (By walls)	NA	NA	NA	1
Areas of special hazard are compartmentalized (Boiler room, Transformer room, Generator room, Storage area of flammable/combustible materials)	0.5	NA	NA	NA

Building material				
Combustibility of building material	1	1	1	1
Combustibility of roofing material	1	0.25	0.25	0.25
Walls and floors				
Fire shutters and curtains are provided	0	0	0	0
Enclosures for ducts passing through are provided	1	1	1	1
Combustibility of floor finishes	1	1	1	1
If building height > 30n				
Fire lift				
At least on fire lift is provided	NA	NA	NA	NA
Natural/mechanical ventilation is provided in fire lift	NA	NA	NA	NA
Fire lift is connected to primary and secondary power supply	NA	NA	NA	NA
If building is a high rise/super high rise/basement with depth over 9m				
Firefighting shaft				
Firefighting shafts provided allowing access to all parts of each story	NA	NA	NA	NA
If building is a super high rise				
Evacuation lift				
Evacuation lift which serves every floor is provided	NA	NA	NA	NA
Evacuation lift can accommodate a stretcher	NA	NA	NA	NA
Total	4.5	3.25	3.25	4.25
Index	0.64	0.54	0.54	0.61
Accessibility to fire brigade				
Criteria	Score			
	Building 1	Building 2	Building 3	Building 4
Access way width	1	1	0	0
Clear working space	1	0.5	0	0
Access to staircase to basement is within 18m of fire vehicle stop	NA	NA	NA	NA
There is easy access to areas of special hazard	0	NA	NA	0
Total	2	1.5	0	0
Index	0.67	0.75	0.00	0.00

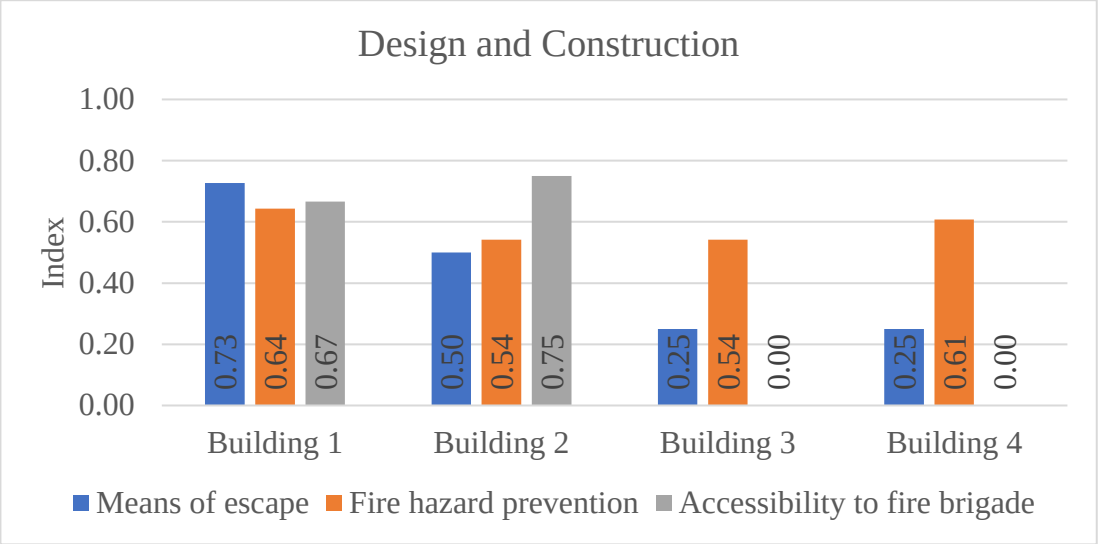

Figure 81: Hospital A -Design and construction assessment

Table 25: Hospital A – Operation and maintenance assessment

Means of Escape	
Criteria	Score
Accessibility of areas designated for escape (Exit staircase, smoke stop lobby, exit passageway and corridor)	1
Final exits lead to a place of total safety	0.75
Condition of floors and stairway surfaces	0.75
Emergency lighting is provided in the stairways	1
Appropriate provisions have been made for the safety of people with special needs	0.25
Assembly points	0.5
Signs	
Escape ways have been indicated by signs	0
Floor levels are indicated by signs	0
Evacuation maps are present	0
Assembly point signs are present	0
Fire Action notices are displayed	0
Fire safety notices and signs are present and clearly visible	0
"Push bar to open" sign present on fire doors	NA
Total	4.25
Index	0.35
Fire detection and alarm systems	
Criteria	Score
Smoke/Heat detectors are installed	0

Manual call points are provided	0
Emergency alarm provided	1
Fire alarm	0.5
Alarm control panel (manned 24/7) is provided	0
Emergency Communication System (ECS)	0
Total	1.5
Index	0.25
Active fire protection systems	
Criteria	Score
Automatic sprinkler system present	0
Separate water supply for sprinklers and hose reels provided	0
Fire blankets have been provided in high risk areas (such as kitchen, laboratory)	0.5
Fire extinguishers	
Fire extinguishers have been sufficiently provided and are easily accessible	1
Posters describing the use of extinguishers available	0
Hose reels	
Located sufficiently in each floor	0.25
Located so that each area of the buildings can be reached	0.25
Hose reel cabinet is unlocked	1
If access to fire vehicle is restricted	
External pillar hydrants are provided	NA
Total	3
Index	0.38
Fire Hazard Prevention	
Criteria	Score
General	
Highly flammable materials are kept out of the basements	NA
Hospital does not have fire spreading material in doors or windows (E.g. Curtains)	0
Quantities and storage of flammable materials are controlled	0.5
Suitable means to control arson are present	1
Waste management	
Waste is separated	1
Waste storage is in a good condition and properly controlled	0.5
Waste is regularly collected	1
Waste storage area has minimum exposure to fire hazards	0
Kitchen	
Automatic fire suppression system provided in cooking range	0
Kitchen gas storage	
Gas cylinders have minimum exposure to excessive temperature rise and tampering	1
Gas cylinders are stored against an outside wall	1

Heating appliances	
All heating appliances are securely fixed in position and secured	1
There is no flammable material stored near heating appliances	1
Fuel storage	
Fuel storage is secured and has minimum exposure to fire	0
Electrical safety	
The entire electrical installation is in order	1
The electrical circuits are free of evidence of overloading	0.5
Electrical equipment is kept away from combustible materials	0
Total	9.5
Index	0.59
Firefighting	
Criteria	Score
Vehicle parking has not blocked access to fire brigade vehicles	0
Access openings are unobstructed	1
Fire service department is familiar with the premises	1
Total	2
Index	0.67

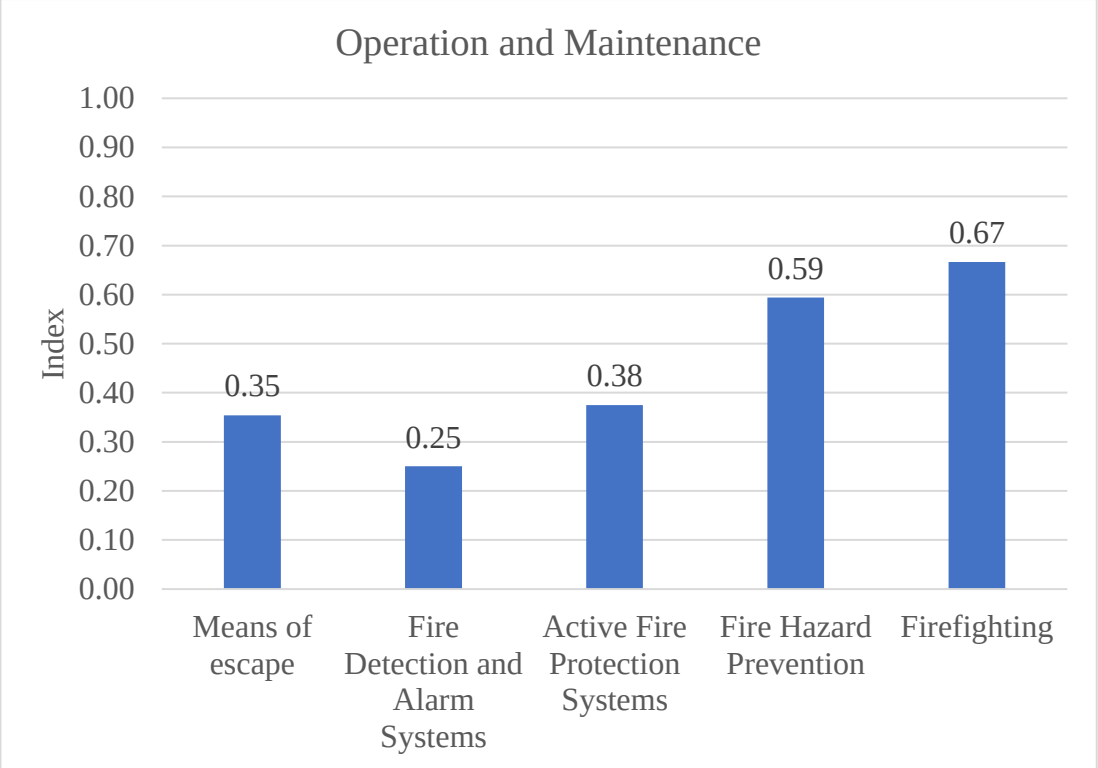

Figure 82: Hospital A - Operation and maintenance assessment

Table 26: Hospital A - Fire hazard management assessment

Disaster Planning	
Criteria	Score
Hospital Disaster Management Plan (HDMO)	0
Incident Reporting System (IRS)	0.5
Fire Action Plan (FAP)	0
Emergency Evacuation Procedures (EEP)	0
Emergency Response Team (ERT)	0
Defined procedures to control alteration, repair and decoration work	0.5
Insurance	0.5
Total	1.5
Index	0.21
Staff Training	
Criteria	Score
Staff have received fire prevention instruction	0.5
Staff have received training in use of fire protection equipment	0.25
Staff have participated in fire drills	0.25
Regularity of fire drills and fire protection training	0.5
Staff have knowledge regarding contacting and obtaining services of the fire service department	0.25
Staff are aware of patient evacuation procedures	0.75
Fire commander (FC)	0.5
Total	3
Index	0.43
Inspection, Maintenance and Testing	
Criteria	Score
At least annual external inspections are conducted	1
Regular maintenance is conducted as necessary	1
Hospital has a servicing contract with a contractor	1
Records of maintenance tests are kept	0
Total	3
Index	0.75

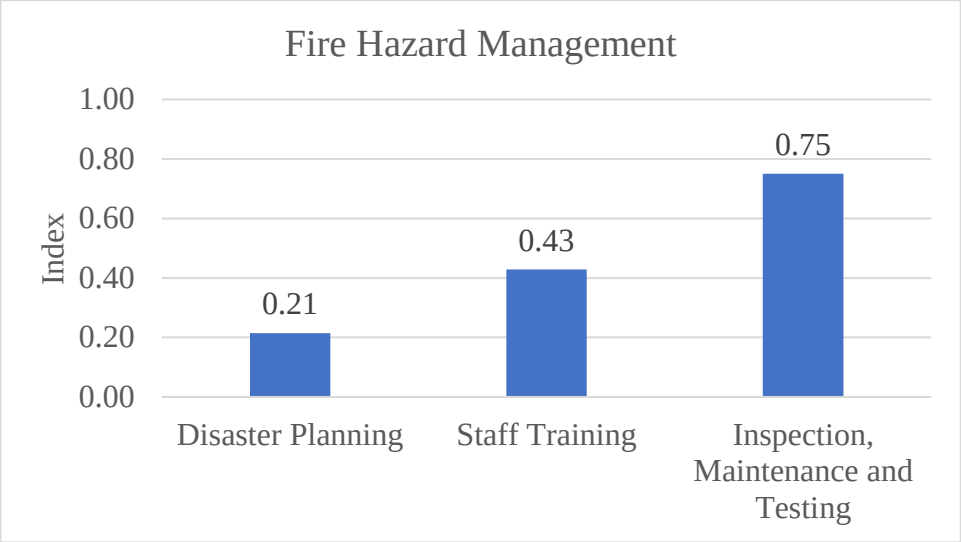

Figure 83: Hospital A - Fire hazard management assessment

Appendix II : Assessment of Hospital B

Table 27: Hospital B - Design and construction assessment

Means of Escape				
Criteria	Score			
	Building 1	Building 2	Building 3	Building 4
Exit door				
Clear width of doors is 1100mm-1250mm	1	1	1	1
Exit doors open in direction of escape	0.25	0.75	0.75	1
Exit doors are self-closing	0	0	0	1
Exit ways				
Number of exit ways from hospital wards	1	1	1	1
Exit stairways				
Number of stairways each floor (Can include ramps, external staircases)	1	1	1	1
Provision of ramps (Applicable if patients stay in the building)	0	1	0	0
Handrails for stairways are provided	1	1	1	1
Access for wheelchairs or trolleys in corridors and stairways				
Access width is greater than 950 mm	1	1	1	1
Smoke stop lobby (If there are 2 or more floors)				
Provision of smoke stop lobby in each floor	0	0	0	0.5
Impedance to escape movements	0	0	0	1
Pressurized ventilation	0	0	0	1
Total	5.25	6.75	5.75	9.5
Index	0.48	0.61	0.52	0.86
Fire Hazard Prevention				
Criteria	Score			
	Building 1	Building 2	Building 3	Building 4
General				
Proximity to buildings	0	0	0.5	0
Kitchen area is separated from other areas (By walls)	NA	1	1	NA
Areas of special hazard are compartmentalized (Boiler room, Transformer room, Generator room, Storage area of flammable/combustible materials)	1	1	1	1

Building material				
Combustibility of building material	1	1	1	1
Combustibility of roofing material	1	1	1	1
Walls and floors				
Fire shutters and curtains are provided	0	0	0	0
Enclosures for ducts passing through are provided	1	1	1	1
Combustibility of floor finishes	1	1	1	1
If building height > 30n				
Fire lift				
At least on fire lift is provided	NA	NA	NA	NA
Natural/mechanical ventilation is provided in fire lift	NA	NA	NA	NA
Fire lift is connected to primary and secondary power supply	NA	NA	NA	NA
If building is a high rise/super high rise/basement with depth over 9m				
Firefighting shaft				
Fire fighting shafts provided allowing access to all parts of each story	NA	NA	NA	NA
If building is a super high rise				
Evacuation lift				
Evacuation lift which serves every floor is provided	NA	NA	NA	NA
Evacuation lift can accommodate a stretcher	NA	NA	NA	NA
Total	5	6	6.5	5
Index	0.71	0.75	0.81	0.71
Accessibility to fire brigade				
Criteria	Score			
	Building 1	Building 2	Building 3	Building 4
Access way width	1	1	1	1
Clear working space	1	1	1	0.5
Access to staircase to basement is within 18m of fire vehicle stop	1	NA	1	NA
There is easy access to areas of special hazard	0	0	1	1
Total	3	2	4	2.5
Index	0.75	0.67	1.00	0.83

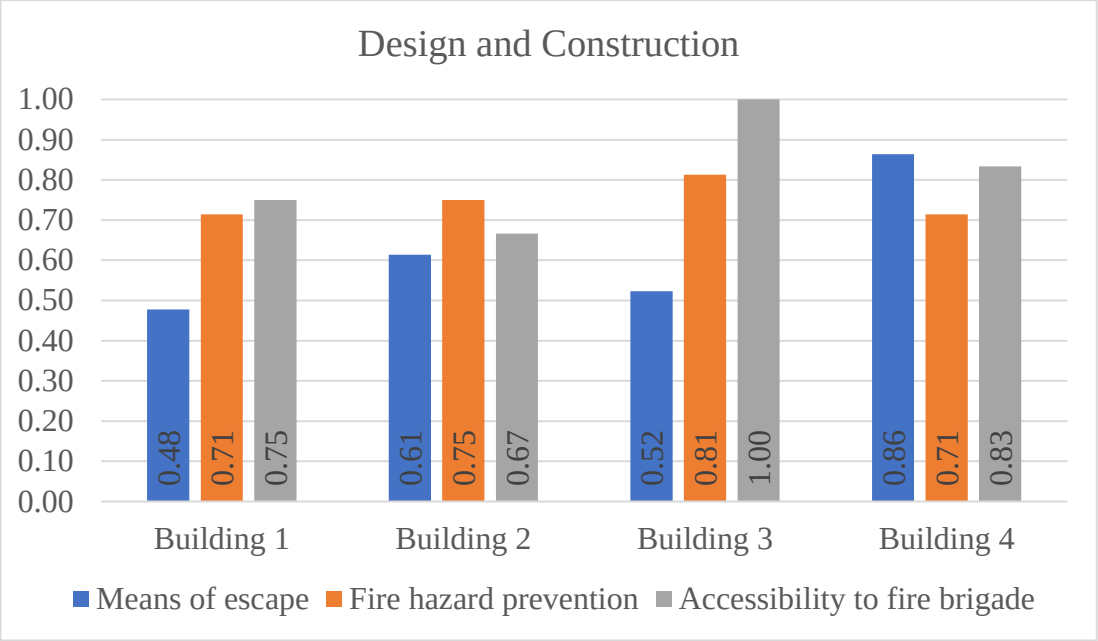

Figure 84: Hospital B - Design and construction assessment

Table 28: Hospital B - Operation and maintenance assesment

Means of Escape	
Criteria	Score
Accessibility of areas designated for escape (Exit staircase, smoke stop lobby, exit passageway and corridor)	1
Final exits lead to a place of total safety	0.75
Condition of floors and stairway surfaces	1
Emergency lighting is provided in the stairways	0.75
Appropriate provisions have been made for the safety of people with special needs	0.25
Assembly points	0
Signs	
Escape ways have been indicated by signs	1
Floor levels are indicated by signs	0
Evacuation maps are present	0
Assembly point signs are present	0
Fire Action notices are displayed	0
Fire safety notices and signs are present and clearly visible	0
"Push bar to open" sign present on fire doors	0
Total	4.75
Index	0.37
Fire detection and alarm systems	
Criteria	Score
Smoke/Heat detectors are installed	0.75

Manual call points are provided	0.75
Emergency alarm provided	1
Fire alarm	1
Alarm control panel (manned 24/7) is provided	0
Emergency Communication System (ECS)	0.5
Total	4
Index	0.67
Active fire protection systems	
Criteria	Score
Automatic sprinkler system present	0.25
Separate water supply for sprinklers and hose reels provided	0
Fire blankets have been provided in high risk areas (such as kitchen, laboratory)	0
Fire extinguishers	
Fire extinguishers have been sufficiently provided and are easily accessible	1
Posters describing the use of extinguishers available	0
Hose reels	
Located sufficiently in each floor	1
Located so that each area of the buildings can be reached	1
Hose reel cabinet is unlocked	1
If access to fire vehicle is restricted	
External pillar hydrants are provided	1
Total	5.25
Index	0.58
Fire Hazard Prevention	
Criteria	Score
General	
Highly flammable materials are kept out of the basements	0
Hospital does not have fire spreading material in doors or windows (Eg. Curtains)	0.5
Quantities and storage of flammable materials are controlled	1
Suitable means to control arson are present	1
Waste management	
Waste is separated	1
Waste storage is in a good condition and properly controlled	1
Waste is regularly collected	1
Waste storage area has minimum exposure to fire hazards	0
Kitchen	
Automatic fire suppression system provided in cooking range	1
Kitchen gas storage	
Gas cylinders have minimum exposure to excessive temperature rise and tampering	1

Gas cylinders are stored against an outside wall	0
Heating appliances	
All heating appliances are securely fixed in position and secured	1
There is no flammable material stored near heating appliances	1
Fuel storage	
Fuel storage is secured and has minimum exposure to fire	0
Electrical safety	
The entire electrical installation is in order	1
The electrical circuits are free of evidence of overloading	0
Electrical equipment is kept away from combustible materials	0.5
Total	11
Index	0.65
Firefighting	
Criteria	Score
Vehicle parking has not blocked access to fire brigade vehicles	1
Access openings are unobstructed	1
Fire service department is familiar with the premises	1
Total	3
Index	1

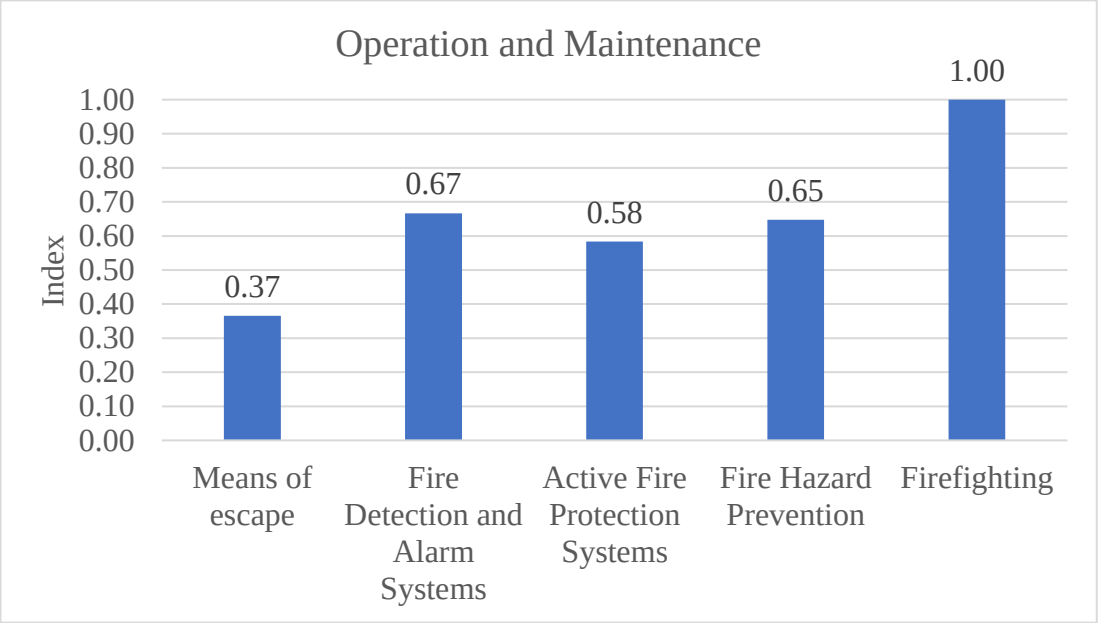

Figure 85: Hospital B - Operation and maintenance assesment

Table 29: Hospital B – Fire hazard management assessment

Disaster Planning	
Criteria	Score
Hospital Disaster Management Plan (HDMO)	0
Incident Reporting System (IRS)	0.5
Fire Action Plan (FAP)	0.5
Emergency Evacuation Procedures (EEP)	0.5
Emergency Response Team (ERT)	0.5
Defined procedures to control alteration, repair and decoration work	0.5
Insurance	0.75
Total	3.25
Index	0.46
Staff Training	
Criteria	Score
Staff have received fire prevention instruction	0.75
Staff have received training in use of fire protection equipment	0.25
Staff have participated in fire drills	0.25
Regularity of fire drills and fire protection training	0.5
Staff have knowledge regarding contacting and obtaining services of the fire service department	0.25
Patient evacuation	0.75
Fire commander (FC)	0.5
Total	3.25
Index	0.46
Inspection, Maintenance and Testing	
Criteria	Score
At least annual external inspections are conducted	1
Regular maintenance is conducted as necessary	1
Hospital has a servicing contract with a contractor	1
Records of maintenance tests are kept	0
Total	3
Index	0.75

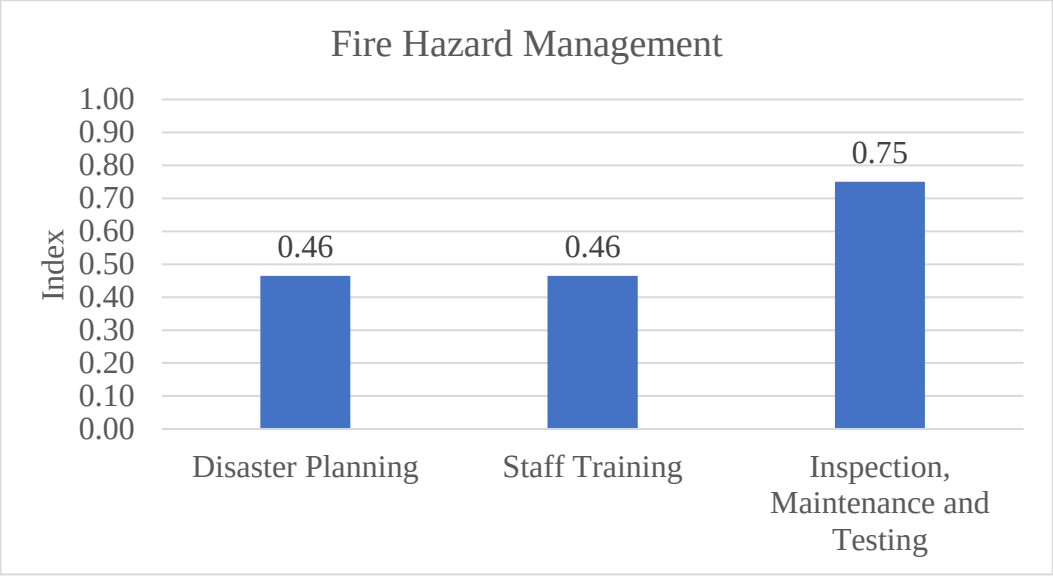

Figure 86: Hospital B – Fire hazard management assessment

Appendix III : Assessment of Hospital C

Table 30: Hospital C - Design and construction assessment

Means of Escape	
Criteria	Score
Exit door	
Clear width of doors is 1100mm-1250mm	1
Exit doors open in direction of escape	1
Exit doors are self-closing	1
Exit ways	
Number of exit ways from hospital wards	1
Exit stairways	
Number of stairways each floor (Can include ramps, external staircases)	1
Provision of ramps (Applicable if patients stay in the building)	0
Handrails for stairways are provided	1
Access for wheelchairs or trolleys in corridors and stairways	
Access width is greater than 950 mm	1
Smoke stop lobby (If there are 2 or more floors)	
Provision of smoke stop lobby in each floor	1
Impedance to escape movements	1
Pressurized ventilation	1
Total	10
Index	0.91
Fire Hazard Prevention	
Criteria	Score
General	
Proximity to buildings	1
Kitchen area is separated from other areas (By walls)	1
Areas of special hazard are compartmentalized (Boiler room, Transformer room, Generator room, Storage area of flammable/combustible materials)	1
Building material	
Combustibility of building material	1
Combustibility of roofing material	1
Walls and floors	
Fire shutters and curtains are provided	0
Enclosures for ducts passing through are provided	1
Combustibility of floor finishes	1
If building height > 30m	
Fire lift	
At least on fire lift is provided	1
Natural/mechanical ventilation is provided in fire lift	1

Fire lift is connected to primary and secondary power supply	1
If building is a high rise/super high rise/basement with depth over 9m	
Firefighting shaft	
Firefighting shafts provided allowing access to all parts of each story	NA
If building is a super high rise	
Evacuation lift	
Evacuation lift which serves every floor is provided	NA
Evacuation lift can accommodate a stretcher	NA
Total	10
Index	0.91
Accessibility to fire brigade	
Criteria	Score
Access way width	1
Clear working space	1
Access to staircase to basement is within 18m of fire vehicle stop	NA
There is easy access to areas of special hazard	1
Total	3
Index	1

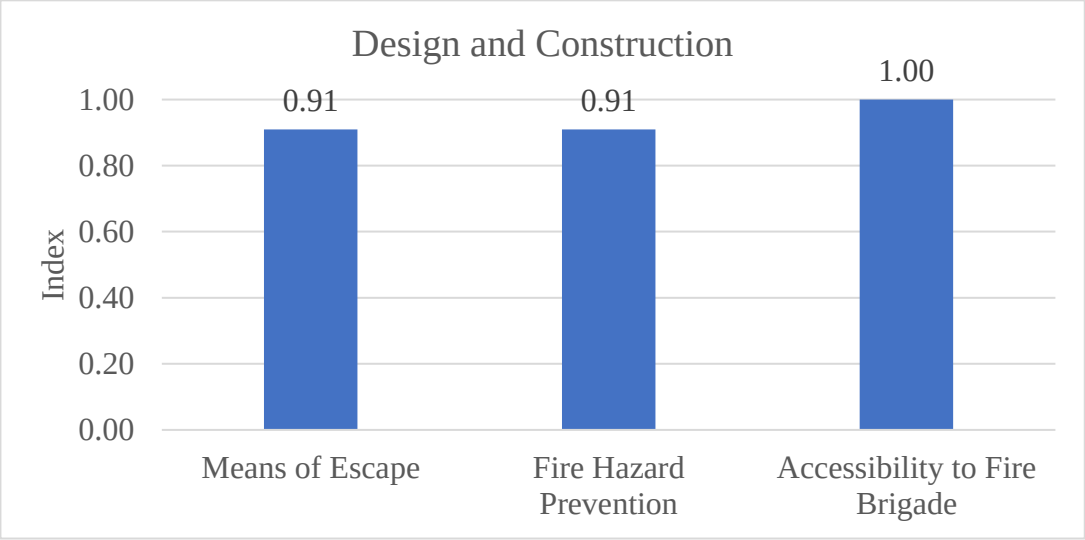

Figure 87: Hospital C - Design and construction assessment

Table 31: Hospital C – Operation and maintenance assessment

Means of Escape	
Criteria	Score
Accessibility of areas designated for escape (Exit staircase, smoke stop lobby, exit passageway and corridor)	1
Final exits lead to a place of total safety	1
Condition of floors and stairway surfaces	1
Emergency lighting is provided in the stairways	1
Appropriate provisions have been made for the safety of people with special needs	0.75
Assembly points	1
Signs	
Escape ways have been indicated by signs	1
Floor levels are indicated by signs	0.75
Evacuation maps are present	1
Assembly point signs are present	1
Fire Action notices are displayed	0.75
Fire safety notices and signs are present and clearly visible	0.75
"Push bar to open" sign present on fire doors	1
Total	12
Index	0.92
Fire detection and alarm systems	
Criteria	Score
Smoke/Heat detectors are installed	1
Manual call points are provided	1
Emergency alarm provided	1
Fire alarm	0.5
Alarm control panel (manned 24/7) is provided	1
Emergency Communication System (ECS)	1
Total	5.5
Index	0.92
Active fire protection systems	
Criteria	Score
Automatic sprinkler system present	1
Separate water supply for sprinklers and hose reels provided	1
Fire blankets have been provided in high risk areas (such as kitchen, laboratory)	0.5
Fire extinguishers	
Fire extinguishers have been sufficiently provided and are easily accessible	1
Posters describing the use of extinguishers available	0

Hose reels	
Located sufficiently in each floor	1
Located so that each area of the buildings can be reached	1
Hose reel cabinet is unlocked	1
If access to fire vehicle is restricted	
External pillar hydrants are provided	1
Total	7.5
Index	0.83
Fire Hazard Prevention	
Criteria	Score
General	
Highly flammable materials are kept out of the basements	NA
Hospital does not have fire spreading material in doors or windows (E.g. Curtains)	1
Quantities and storage of flammable materials are controlled	1
Suitable means to control arson are present	1
Waste management	
Waste is separated	1
Waste storage is in a good condition and properly controlled	1
Waste is regularly collected	1
Waste storage area has minimum exposure to fire hazards	1
Kitchen	
Automatic fire suppression system provided in cooking range	1
Kitchen gas storage	
Gas cylinders have minimum exposure to excessive temperature rise and tampering	1
Gas cylinders are stored against an outside wall	1
Heating appliances	
All heating appliances are securely fixed in position and secured	1
There are no flammable material stored near heating appliances	1
Fuel storage	
Fuel storage is secured and has minimum exposure to fire	1
Electrical safety	
The entire electrical installation is in order	1
The electrical circuits are free of evidence of overloading	1
Electrical equipment is kept away from combustible materials	1
Total	16
Index	1
Firefighting	
Criteria	Score
Vehicle parking has not blocked access to fire brigade vehicles	1
Access openings are unobstructed	1
Fire service department is familiar with the premises	1

Total	3
Index	1

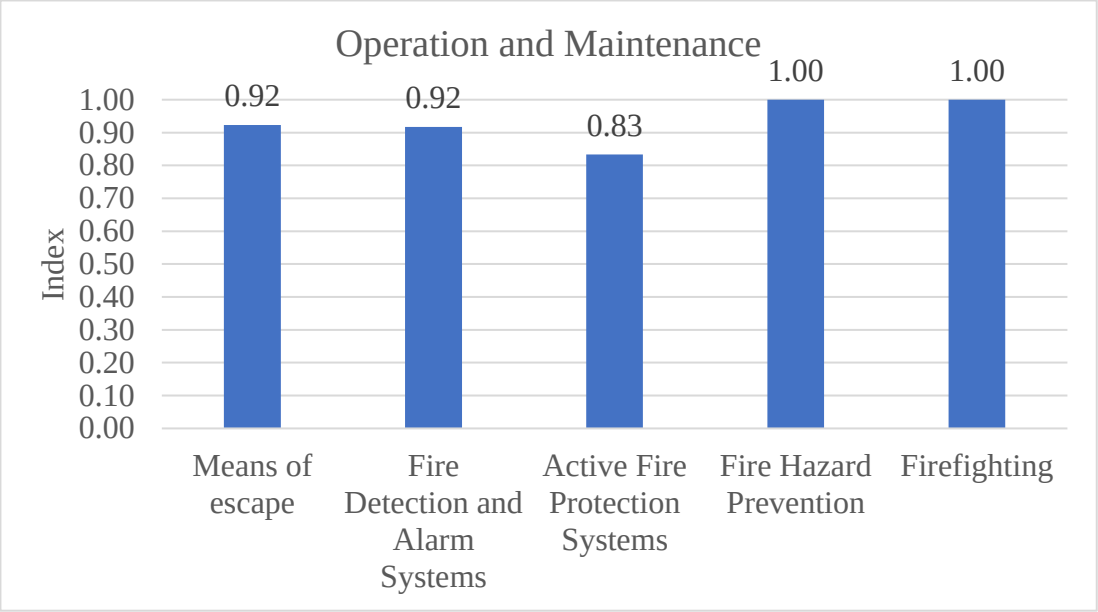

Figure 88: Hospital C – Operation and maintenance assessment

Table 32: Hospital C - Fire hazard management assessment

Disaster Planning	
Criteria	Score
Hospital Disaster Management Plan (HDMO)	1
Incident Reporting System (IRS)	1
Fire Action Plan (FAP)	1
Emergency Evacuation Procedures (EEP)	1
Emergency Response Team (ERT)	1
Defined procedures to control alteration, repair and decoration work	1
Insurance	0.75
Total	6.75
Index	0.96
Staff Training	
Criteria	Score
Staff have received fire prevention instruction	1
Staff have received training in use of fire protection equipment	1
Staff have participated in fire drills	1
Regularity of fire drills and fire protection training	1
Staff have knowledge regarding contacting and obtaining services of the fire service department	1
Patient evacuation	1
Fire commander (FC)	1
Total	7
Index	1.00
Inspection, Maintenance and Testing	
Criteria	Score
At least annual external inspections are conducted	1
Regular maintenance is conducted as necessary	1
Hospital has a servicing contract with a contractor	1
Records of maintenance tests are kept	1
Total	4
Index	1.00

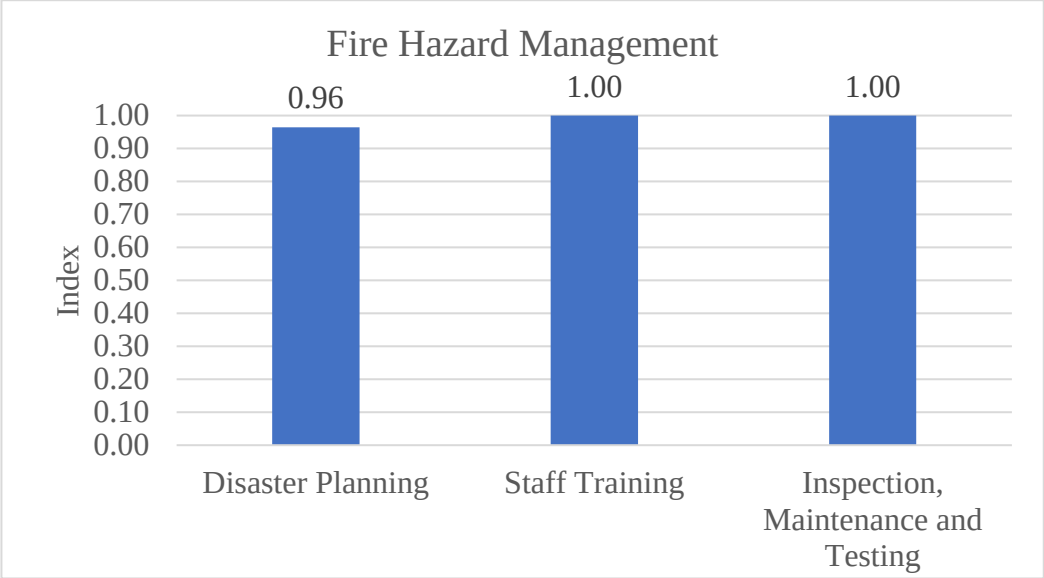

Figure 89: Hospital C - Fire hazard management assessment

Appendix IV : Assessment of DH Q

Table 33: DH Q - Design and construction assessment

Means of Escape	
Criteria	Score
Exit door	
Clear width of doors is 1100mm-1250mm	1
Exit doors open in direction of escape	1
Exit doors are self-closing	0
Exit ways	
Number of exit ways from hospital wards	1
Exit stairways	
Number of stairways each floor (Can include ramps, external staircases)	NA
Provision of ramps (Applicable if patients stay in the building)	NA
Handrails for stairways are provided	NA
Access for wheelchairs or trolleys in corridors and stairways	
Access width is greater than 950 mm	1
Smoke stop lobby (If there are 2 or more floors)	
Provision of smoke stop lobby in each floor	NA
Impedance to escape movements	NA
Pressurized ventilation	NA
Total	4
Index	0.80
Fire Hazard Prevention	
Criteria	Score
General	
Proximity to buildings	1
Kitchen area is separated from other areas (By walls)	1
Areas of special hazard are compartmentalized (Boiler room, Transformer room, Generator room, Storage area of flammable/combustible materials)	1
Building material	
Combustibility of building material	1
Combustibility of roofing material	1
Walls and floors	
Fire shutters and curtains are provided	0
Enclosures for ducts passing through are provided	1
Combustibility of floor finishes	1
If building height > 30m	
Fire lift	
At least on fire lift is provided	NA
Natural/mechanical ventilation is provided in fire lift	NA

Fire lift is connected to primary and secondary power supply	NA
If building is a high rise/super high rise/basement with depth over 9m	
Firefighting shaft	
Firefighting shafts provided allowing access to all parts of each story	NA
If building is a super high rise	
Evacuation lift	
Evacuation lift which serves every floor is provided	NA
Evacuation lift can accommodate a stretcher	NA
Total	7
Index	0.88
Accessibility to fire brigade	
Criteria	Score
Access way width	1
Clear working space	1
Access to staircase to basement is within 18m of fire vehicle stop	NA
There is easy access to areas of special hazard	1
Total	3
Index	1

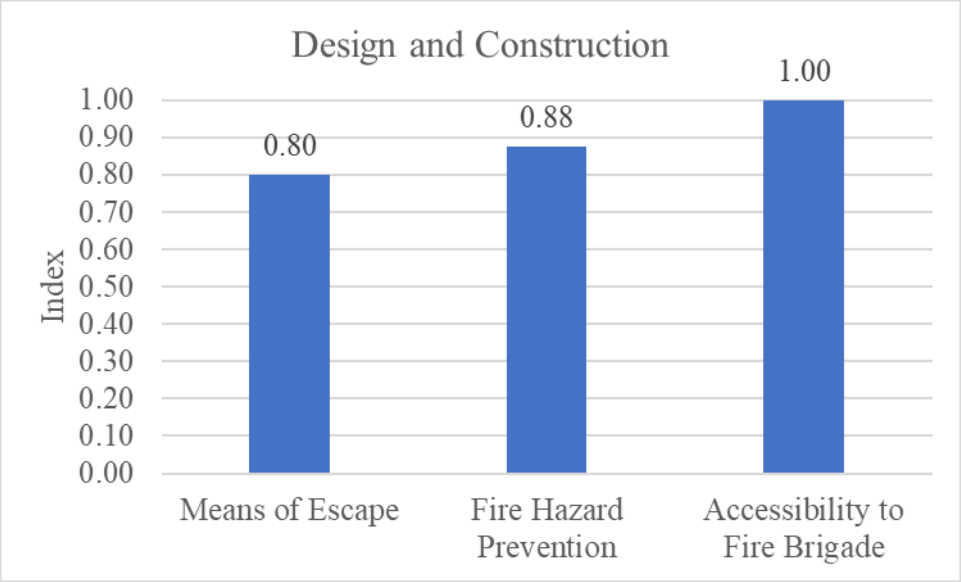

Figure 90: DH Q - Design and construction assessment

Table 34: DH Q - Operation and maintenance assessment

Means of Escape	
Criteria	Score
Accessibility of areas designated for escape (Exit staircase, smoke stop lobby, exit passageway and corridor)	1
Final exits lead to a place of total safety	1
Condition of floors and stairway surfaces	0.75
Emergency lighting is provided in the stairways	NA
Appropriate provisions have been made for the safety of people with special needs	0.5
Assembly points	0
Signs	
Escape ways have been indicated by signs	0
Floor levels are indicated by signs	NA
Evacuation maps are present	0
Assembly point signs are present	0
Fire Action notices are displayed	0
Fire safety notices and signs are present and clearly visible	0
"Push bar to open" sign present on fire doors	NA
Total	3.25
Index	0.33
Fire detection and alarm systems	
Criteria	Score
Smoke/Heat detectors are installed	0
Manual call points are provided	0
Emergency alarm provided	0
Fire alarm	0
Alarm control panel (manned 24/7) is provided	0
Emergency Communication System (ECS)	0
Total	0
Index	0.00
Active fire protection systems	
Criteria	Score
Automatic sprinkler system present	0
Separate water supply for sprinklers and hose reels provided	0
Fire blankets have been provided in high risk areas (such as kitchen, laboratory)	0
Fire extinguishers	
Fire extinguishers have been sufficiently provided and are easily accessible	0.5
Posters describing the use of extinguishers available	0
Hose reels	
Located sufficiently in each floor	0
Located so that each area of the buildings can be reached	0

Hose reel cabinet is unlocked	0
If access to fire vehicle is restricted	
External pillar hydrants are provided	NA
Total	0.5
Index	0.06
Fire Hazard Prevention	
Criteria	Score
General	
Highly flammable materials are kept out of the basements	NA
Hospital does not have fire spreading material in doors or windows (E.g. Curtains)	0.5
Quantities and storage of flammable materials are controlled	1
Suitable means to control arson are present	0.5
Waste management	
Waste is separated	1
Waste storage is in a good condition and properly controlled	1
Waste is regularly collected	1
Waste storage area has minimum exposure to fire hazards	1
Kitchen	
Automatic fire suppression system provided in cooking range	0
Kitchen gas storage	
Gas cylinders have minimum exposure to excessive temperature rise and tampering	1
Gas cylinders are stored against an outside wall	1
Heating appliances	
All heating appliances are securely fixed in position and secured	1
There is no flammable material stored near heating appliances	1
Fuel storage	
Fuel storage is secured and has minimum exposure to fire	1
Electrical safety	
The entire electrical installation is in order	1
The electrical circuits are free of evidence of overloading	1
Electrical equipment is kept away from combustible materials	1
Total	14
Index	0.875
Firefighting	
Criteria	Score
Vehicle parking has not blocked access to fire brigade vehicles	1
Access openings are unobstructed	1
Fire service department is familiar with the premises	1
Total	3
Index	1

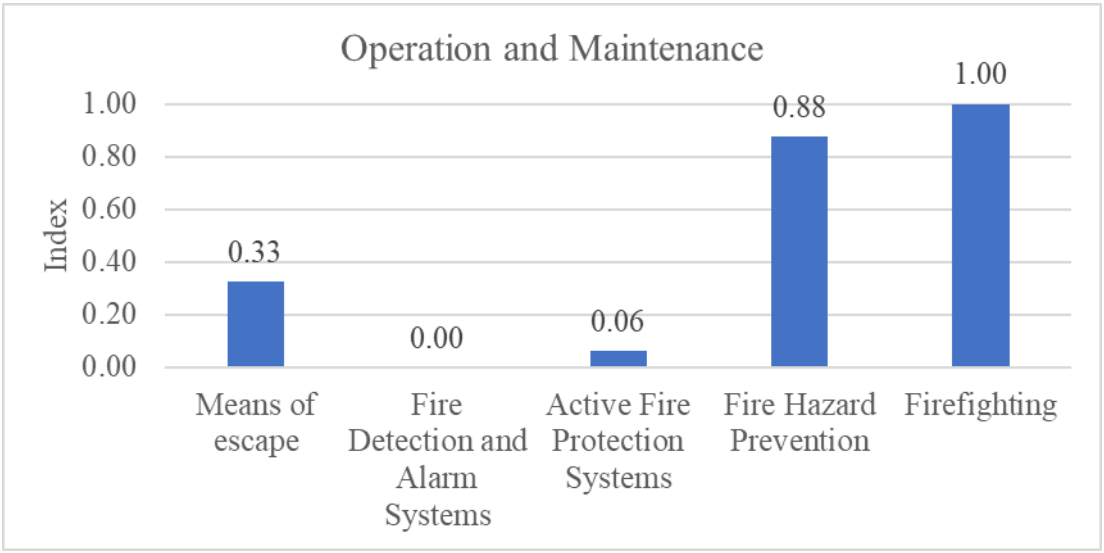

Figure 91: DH Q - Operation and maintenance assessment

Table 35: DH Q - Fire hazard management assessment

Disaster Planning	
Criteria	Score
Hospital Disaster Management Plan (HDMO)	0
Incident Reporting System (IRS)	0
Fire Action Plan (FAP)	0
Emergency Evacuation Procedures (EEP)	0
Emergency Response Team (ERT)	0
Defined procedures to control alteration, repair and decoration work	0.5
Insurance	0
Total	1.25
Index	0.18
Staff Training	
Criteria	Score
Staff have received fire prevention instruction	0
Staff have received training in use of fire protection equipment	0
Staff have participated in fire drills	0
Regularity of fire drills and fire protection training	0
Staff have knowledge regarding contacting and obtaining services of the fire service department	0.25
Patient evacuation	0.75
Fire commander (FC)	0
Total	1
Index	0.14
Inspection, Maintenance and Testing	
Criteria	Score
At least annual external inspections are conducted	0
Regular maintenance is conducted as necessary	1
Hospital has a servicing contract with a contractor	0
Records of maintenance tests are kept	0
Total	1
Index	0.25

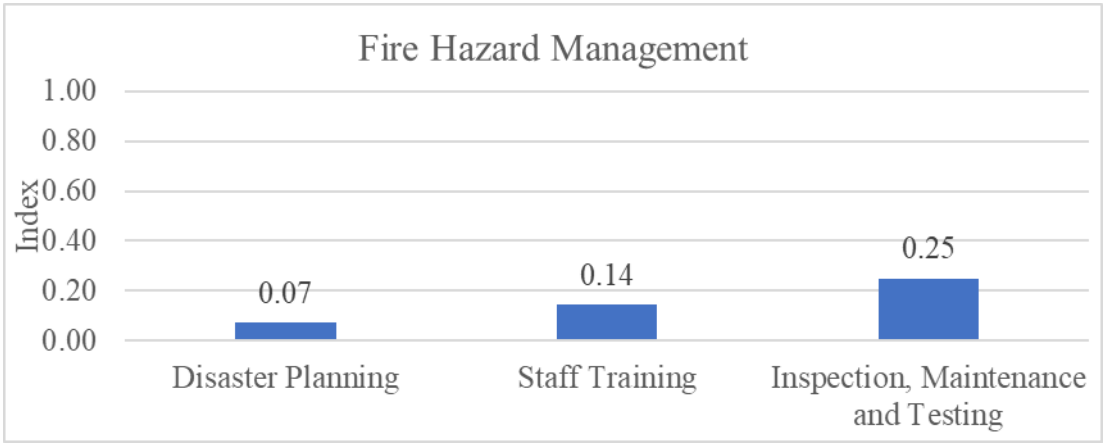

Figure 92: DH Q - Fire hazard management assessment

Appendix V : Assessment of BH U

Table 36: BH U - Desgin and construction assesment

Means of Escape	
Criteria	Score
Exit door	
Clear width of doors is 1100mm-1250mm	1
Exit doors open in direction of escape	0.75
Exit doors are self-closing	0
Exit ways	
Number of exit ways from hospital wards	1
Exit stairways	
Number of stairways each floor (Can include ramps, external staircases)	1
Provision of ramps (Applicable if patients stay in the building)	1
Handrails for stairways are provided	1
Access for wheelchairs or trolleys in corridors and stairways	
Access width is greater than 950 mm	1
Smoke stop lobby (If there are 2 or more floors)	
Provision of smoke stop lobby in each floor	0
Impedance to escape movements	0
Pressurized ventilation	0
Total	6.75
Index	0.61
Fire Hazard Prevention	
Criteria	Score
General	
Proximity to buildings	0.5
Kitchen area is separated from other areas (By walls)	1
Areas of special hazard are compartmentalized (Boiler room, Transformer room, Generator room, Storage area of flammable/combustible materials)	1
Building material	
Combustibility of building material	1
Combustibility of roofing material	1
Walls and floors	
Fire shutters and curtains are provided	0
Enclosures for ducts passing through are provided	1
Combustibility of floor finishes	1
If building height > 30m	
Fire lift	
At least on fire lift is provided	NA
Natural/mechanical ventilation is provided in fire lift	NA

Fire lift is connected to primary and secondary power supply	NA
If building is a high rise/super high rise/basement with depth over 9m	
Firefighting shaft	
Firefighting shafts provided allowing access to all parts of each story	NA
If building is a super high rise	
Evacuation lift	
Evacuation lift which serves every floor is provided	NA
Evacuation lift can accommodate a stretcher	NA
Total	6.5
Index	0.81
Accessibility to fire brigade	
Criteria	Score
Access way width	1
Clear working space	0.5
Access to staircase to basement is within 18m of fire vehicle stop	NA
There is easy access to areas of special hazard	0
Total	1.5
Index	0.5

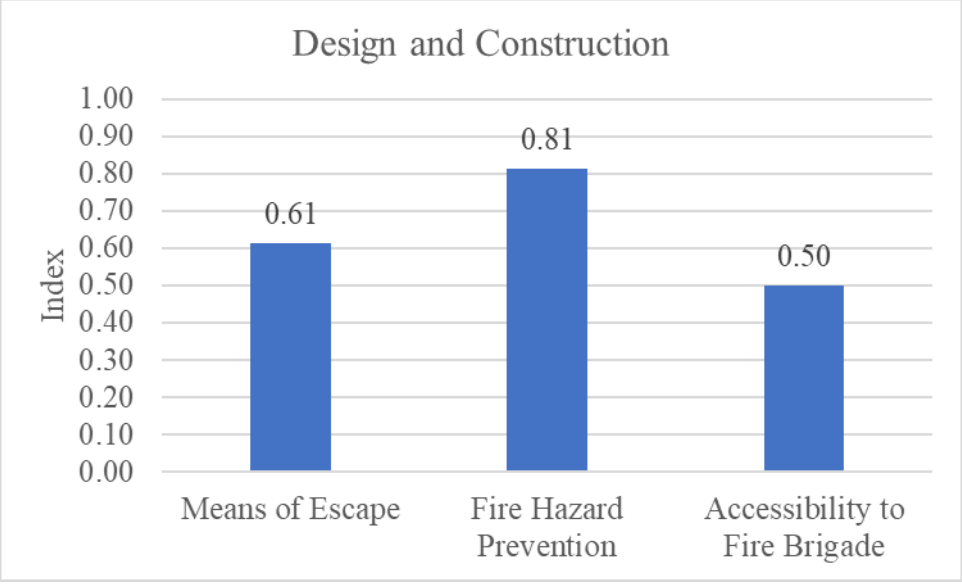

Figure 93:BH U - Design and construction assessment

Table 37: BH U - Operation and maintenance assessment

Means of Escape	
Criteria	Score
Accessibility of areas designated for escape (Exit staircase, smoke stop lobby, exit passageway and corridor)	1
Final exits lead to a place of total safety	0.5
Condition of floors and stairway surfaces	0.75
Emergency lighting is provided in the stairways	0.25
Appropriate provisions have been made for the safety of people with special needs	1
Assembly points	0
Signs	
Escape ways have been indicated by signs	0.5
Floor levels are indicated by signs	1
Evacuation maps are present	0
Assembly point signs are present	0
Fire Action notices are displayed	0
Fire safety notices and signs are present and clearly visible	0
"Push bar to open" sign present on fire doors	NA
Total	5
Index	0.42
Fire detection and alarm systems	
Criteria	Score
Smoke/Heat detectors are installed	0
Manual call points are provided	0
Emergency alarm provided	0
Fire alarm	0
Alarm control panel (manned 24/7) is provided	0
Emergency Communication System (ECS)	0.5
Total	0.5
Index	0.08
Active fire protection systems	
Criteria	Score
Automatic sprinkler system present	0
Separate water supply for sprinklers and hose reels provided	0
Fire blankets have been provided in high risk areas (such as kitchen, laboratory)	0
Fire extinguishers	
Fire extinguishers have been sufficiently provided and are easily accessible	0.75
Posters describing the use of extinguishers available	0
Hose reels	
Located sufficiently in each floor	0.75
Located so that each area of the buildings can be reached	0.75

Hose reel cabinet is unlocked	1
If access to fire vehicle is restricted	
External pillar hydrants are provided	NA
Total	3.25
Index	0.41
Fire Hazard Prevention	
Criteria	Score
General	
Highly flammable materials are kept out of the basements	NA
Hospital does not have fire spreading material in doors or windows (E.g. Curtains)	0.5
Quantities and storage of flammable materials are controlled	1
Suitable means to control arson are present	0.5
Waste management	
Waste is separated	1
Waste storage is in a good condition and properly controlled	1
Waste is regularly collected	1
Waste storage area has minimum exposure to fire hazards	1
Kitchen	
Automatic fire suppression system provided in cooking range	0
Kitchen gas storage	
Gas cylinders have minimum exposure to excessive temperature rise and tampering	1
Gas cylinders are stored against an outside wall	1
Heating appliances	
All heating appliances are securely fixed in position and secured	1
There is no flammable material stored near heating appliances	1
Fuel storage	
Fuel storage is secured and has minimum exposure to fire	0.5
Electrical safety	
The entire electrical installation is in order	0.5
The electrical circuits are free of evidence of overloading	0
Electrical equipment is kept away from combustible materials	1
Total	12
Index	0.75
Firefighting	
Criteria	Score
Vehicle parking has not blocked access to fire brigade vehicles	0.5
Access openings are unobstructed	0.5
Fire service department is familiar with the premises	1
Total	2
Index	0.67

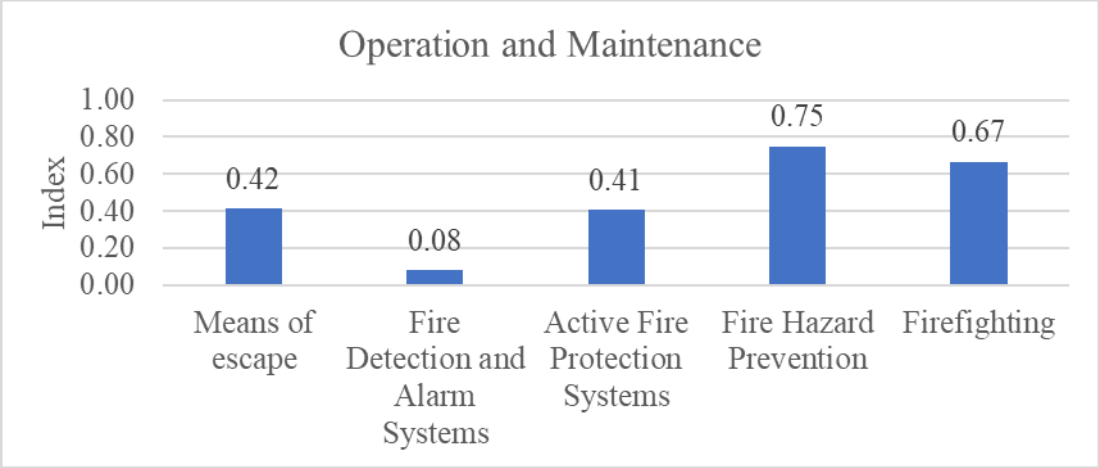

Figure 94: BH U - Operation and maintenance assessment

Table 38: BH U - Fire hazard management assessment

Disaster Planning	
Criteria	Score
Hospital Disaster Management Plan (HDMO)	0.5
Incident Reporting System (IRS)	0
Fire Action Plan (FAP)	1
Emergency Evacuation Procedures (EEP)	0.5
Emergency Response Team (ERT)	0
Defined procedures to control alteration, repair and decoration work	0.5
Insurance	0
Total	2.5
Index	0.36
Staff Training	
Criteria	Score
Staff have received fire prevention instruction	0.5
Staff have received training in use of fire protection equipment	0.5
Staff have participated in fire drills	0.25
Regularity of fire drills and fire protection training	0
Staff have knowledge regarding contacting and obtaining services of the fire service department	0.25
Patient evacuation	0.75
Fire commander (FC)	0
Total	2.25
Index	0.32
Inspection, Maintenance and Testing	
Criteria	Score
At least annual external inspections are conducted	0
Regular maintenance is conducted as necessary	1
Hospital has a servicing contract with a contractor	0
Records of maintenance tests are kept	0
Total	1
Index	0.25

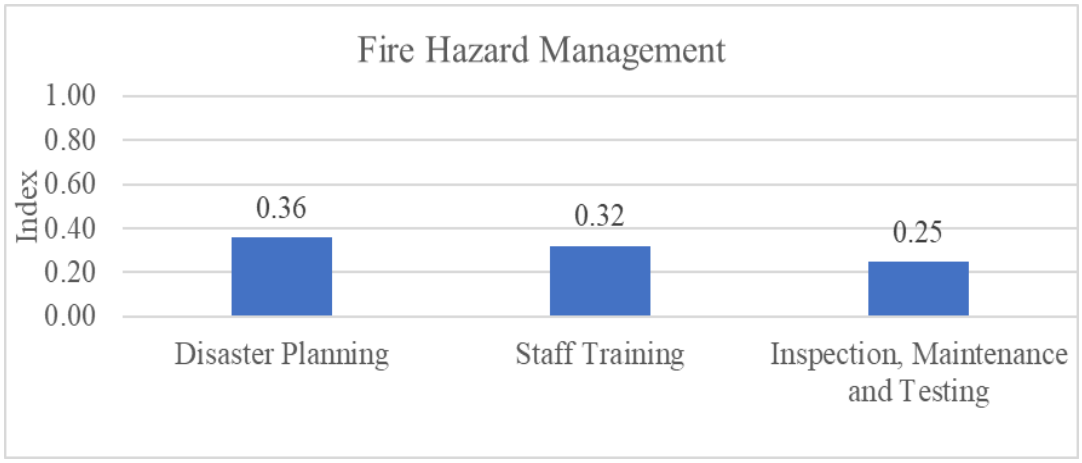

Figure 95: BH U - Fire hazard management assessment

Appendix VI : Assessment of DGH S

Table 39: DGH Matara - Design and construction assessment

Means of Escape	
Criteria	Score
Exit door	
Clear width of doors is 1100mm-1250mm	1
Exit doors open in direction of escape	0.75
Exit doors are self-closing	0
Exit ways	
Number of exit ways from hospital wards	1
Exit stairways	
Number of stairways each floor (Can include ramps, external staircases)	1
Provision of ramps (Applicable if patients stay in the building)	0
Handrails for stairways are provided	1
Access for wheelchairs or trolleys in corridors and stairways	
Access width is greater than 950 mm	1
Smoke stop lobby (If there are 2 or more floors)	
Provision of smoke stop lobby in each floor	0
Impedance to escape movements	0
Pressurized ventilation	0
Total	5.75
Index	0.52
Fire Hazard Prevention	
Criteria	Score
General	
Proximity to buildings	0.5
Kitchen area is separated from other areas (By walls)	1
Areas of special hazard are compartmentalized (Boiler room, Transformer room, Generator room, Storage area of flammable/combustible materials)	1
Building material	
Combustibility of building material	1
Combustibility of roofing material	1
Walls and floors	
Fire shutters and curtains are provided	0
Enclosures for ducts passing through are provided	1
Combustibility of floor finishes	1
If building height > 30m	
Fire lift	
At least on fire lift is provided	NA
Natural/mechanical ventilation is provided in fire lift	NA

Fire lift is connected to primary and secondary power supply	NA
If building is a high rise/super high rise/basement with depth over 9m	
Firefighting shaft	
Firefighting shafts provided allowing access to all parts of each story	NA
If building is a super high rise	
Evacuation lift	
Evacuation lift which serves every floor is provided	NA
Evacuation lift can accommodate a stretcher	NA
Total	6.5
Index	0.81
Accessibility to fire brigade	
Criteria	Score
Access way width	0.5
Clear working space	0.5
Access to staircase to basement is within 18m of fire vehicle stop	NA
There is easy access to areas of special hazard	0
Total	1
Index	0.33

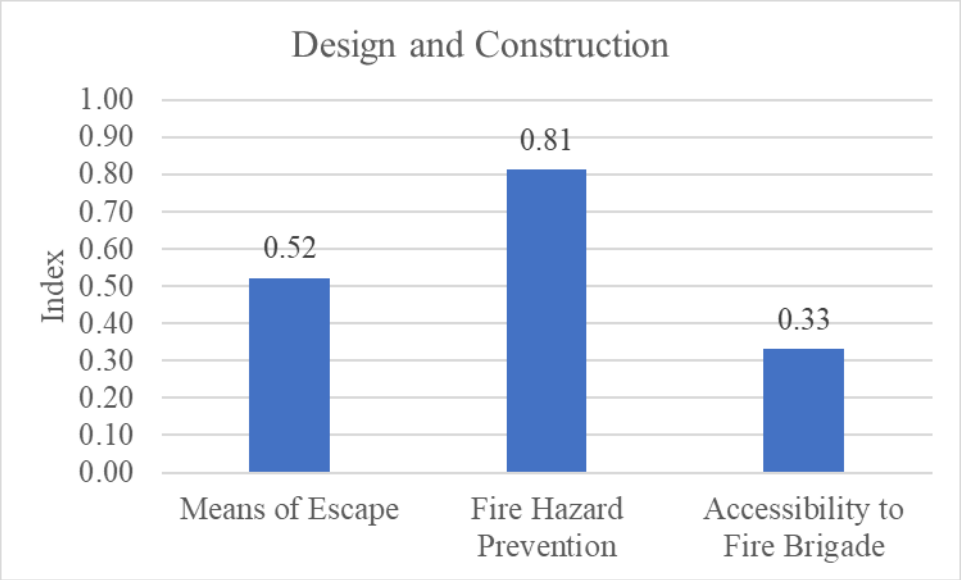

Figure 96: DGH S – Design and construction assessment

Table 40: DGH S - Operation and maintenance assessment

Means of Escape	
Criteria	Score
Accessibility of areas designated for escape (Exit staircase, smoke stop lobby, exit passageway and corridor)	0.5
Final exits lead to a place of total safety	0.5
Condition of floors and stairway surfaces	0.75
Emergency lighting is provided in the stairways	0.5
Appropriate provisions have been made for the safety of people with special needs	0.25
Assembly points	0
Signs	
Escape ways have been indicated by signs	0.5
Floor levels are indicated by signs	1
Evacuation maps are present	0
Assembly point signs are present	0
Fire Action notices are displayed	0
Fire safety notices and signs are present and clearly visible	0
"Push bar to open" sign present on fire doors	NA
Total	4
Index	0.33
Fire detection and alarm systems	
Criteria	Score
Smoke/Heat detectors are installed	0
Manual call points are provided	0
Emergency alarm provided	0
Fire alarm	0
Alarm control panel (manned 24/7) is provided	0
Emergency Communication System (ECS)	0.5
Total	0.5
Index	0.08
Active fire protection systems	
Criteria	Score
Automatic sprinkler system present	0
Separate water supply for sprinklers and hose reels provided	0
Fire blankets have been provided in high risk areas (such as kitchen, laboratory)	0
Fire extinguishers	
Fire extinguishers have been sufficiently provided and are easily accessible	0.25
Posters describing the use of extinguishers available	0
Hose reels	
Located sufficiently in each floor	0.25
Located so that each area of the buildings can be reached	0

Hose reel cabinet is unlocked	1
If access to fire vehicle is restricted	
External pillar hydrants are provided	NA
Total	1.5
Index	0.19
Fire Hazard Prevention	
Criteria	Score
General	
Highly flammable materials are kept out of the basements	NA
Hospital does not have fire spreading material in doors or windows (E.g. Curtains)	0.5
Quantities and storage of flammable materials are controlled	1
Suitable means to control arson are present	0.25
Waste management	
Waste is separated	1
Waste storage is in a good condition and properly controlled	1
Waste is regularly collected	0.5
Waste storage area has minimum exposure to fire hazards	1
Kitchen	
Automatic fire suppression system provided in cooking range	0
Kitchen gas storage	
Gas cylinders have minimum exposure to excessive temperature rise and tampering	0.5
Gas cylinders are stored against an outside wall	0
Heating appliances	
All heating appliances are securely fixed in position and secured	0.5
There are no flammable material stored near heating appliances	0.5
Fuel storage	
Fuel storage is secured and has minimum exposure to fire	1
Electrical safety	
The entire electrical installation is in order	0.5
The electrical circuits are free of evidence of overloading	0
Electrical equipment is kept away from combustible materials	0.5
Total	8.75
Index	0.55
Firefighting	
Criteria	Score
Vehicle parking has not blocked access to fire brigade vehicles	1
Access openings are unobstructed	0.5
Fire service department is familiar with the premises	1
Total	2.5
Index	0.83

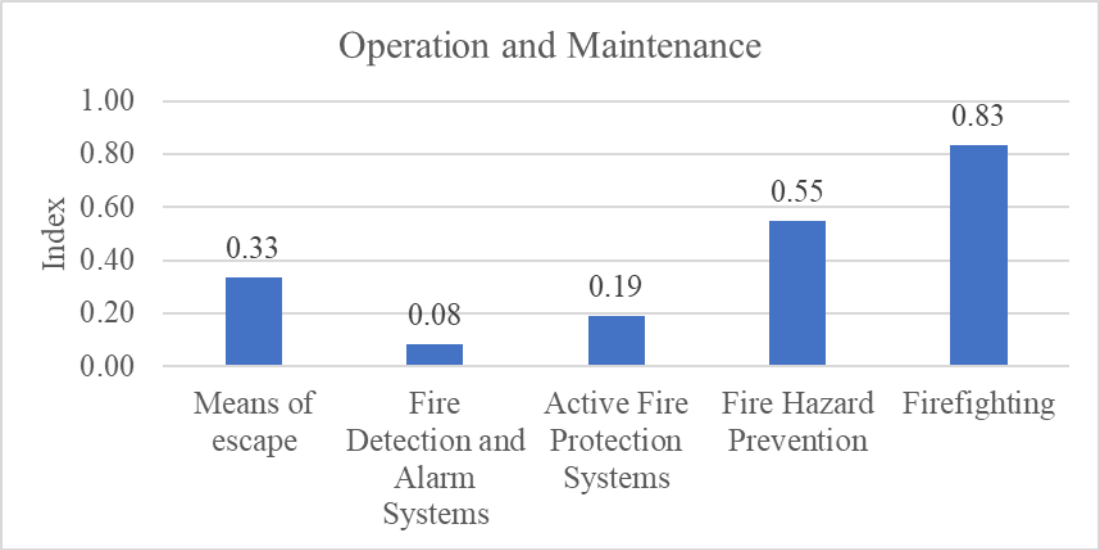

Figure 97: DGH S - Operation and maintenance assessment

Table 41: DGH S - Fire hazard management assessment

Disaster Planning	
Criteria	Score
Hospital Disaster Management Plan (HDMO)	0.25
Incident Reporting System (IRS)	0
Fire Action Plan (FAP)	0
Emergency Evacuation Procedures (EEP)	0.5
Emergency Response Team (ERT)	0.5
Defined procedures to control alteration, repair and decoration work	0.5
Insurance	0
Total	1.75
Index	0.25
Staff Training	
Criteria	Score
Staff have received fire prevention instruction	0.25
Staff have received training in use of fire protection equipment	0.25
Staff have participated in fire drills	0.25
Regularity of fire drills and fire protection training	0
Staff have knowledge regarding contacting and obtaining services of the fire service department	0.25
Patient evacuation	0.75
Fire commander (FC)	0
Total	1.75
Index	0.25
Inspection, Maintenance and Testing	
Criteria	Score
At least annual external inspections are conducted	0
Regular maintenance is conducted as necessary	1
Hospital has a servicing contract with a contractor	0
Records of maintenance tests are kept	0
Total	1
Index	0.25

Figure 98: DGH S - -Fire hazard management assessment

Appendix VII : Questionnaire Form for Hospital Staff

Staff Training for Fire Hazards

Demography

1. Position

Mark only one oval.

- ◯ Medical Officer
- ◯ Nursing Staff
- ◯ Maintenance Staff
- ◯ Office Staff
- ◯ Stores Staff
- ◯ Laboratory Staff
- ◯ Security Staff
- ◯ Supportive staff

2. Gender

Mark only one oval.

- ◯ Female
- ◯ Male

3. Age category

Mark only one oval.

- 20-29
- 30-39
- 40-49
- 50-59
- 60-69
- 70 upwards

4. Number of years worked at the hospital

5. Has previously worked at another hospital

Mark only one oval.

- Yes
- No

6. If having previous experience, hospital was

Mark only one oval.

- Private hospital
- Government hospital
- Both

7. Has any experience with hospital fires in the hospital

Mark only one oval.

- ◯ Yes
- ◯ No

8. If so, how long ago did the incident occur?

_____

9. Give a brief description of the fire

_____

_____

_____

_____

_____

Staff Training and Preparedness

10. Has received basic fire management training

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

11. Has knowledge on using fire protection appliances (fire extinguishers, fire hose reels, etc)

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

12. Has undergone fire drills

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

13. How often staff training for fire safety management is done?

_____

14. Staff duties in the event of a fire

_____

_____

_____

_____

_____

15. How long would it take to evacuate the building?

_____

16. What is the assembly point in the case of an evacuation?

17. In the event of an evacuation, how would you evacuate the patients?

18. Who is the person responsible to alert the fire brigade in the event of a fire?

19. If there is an emergency, how would you sound the alarm?

20. How prepared are you to face a fire hazard in a hospital?

Mark only one oval.

	1	2	3	4	5	
Not prepared at all	◯	◯	◯	◯	◯	Extremely prepared

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Evaluating the Applicability of the "Hospital Safety Index Guide" for the Sri Lankan Context

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***Abstract*—The healthcare systems of a country and its numerous institutions are of considerable importance during the whole lifecycle of a disaster. Therefore, it is crucial that the preparedness level of the hospital including its structures, systems, and stakeholders are identified during the pre-disaster period. Thereby their weaknesses can be found, and steps can be taken to reduce them. In this study, the definition and role of a hospital in Sri Lanka during a disaster has been investigated in the form of a questionnaire. Then the applicability of the Hospital Safety Index (HSI) Guide developed by the World Health Organization (WHO) and the Pan American Health Organization (PAHO) was analyzed. As part of an ongoing study, pilot studies in two tertiary level hospitals in Sri Lanka were carried out. Based on the outcomes, some amendments to the existing checklist were proposed in order to better suit it for Sri Lankan hospitals and the expectations that the general public has of a "Safe Hospital".**

Keywords — Safe Hospital, Resilience, Hospital Safety Index, Disaster Risk Reduction

I INTRODUCTION

The world experiences hazards, including natural hazards such as floods, landslides, and tsunamis, societal hazards such as civil unrest and armed conflicts as well as biological hazards such as the H1N1 epidemic in 2009. Such hazards have a propensity to cause disasters among the society which may result in tragedies such as loss of property, harm to people and sometimes, even death [1].

In Sri Lanka, 2016 and 2017 brought three major disasters. Flooding in the Kelaniya river basin and landslides in Aranayaka in May 2016 affected 340,150 people and caused the deaths of 84 people. In April 2017, the garbage dump in Meetotamulla collapsed, causing 32 deaths. The Cyclone Mora in May 2017 affected 15 districts causing more than 200 deaths [208].

Hospitals are complex systems and it is vital that a hospital can remain accessible, functional and safe at maximum capacity during and immediately after the occurrence of a disaster or emergency [209]. A hospital system has many activities occurring within it at all times, ranging from major medical care to other activities such as food preparation for patients. It is a big people's zone with many types of stakeholders such as doctors, nurses, supportive staff and patients. Because of this complexity, sometimes people mistakenly assume hospitals to be independent and isolated systems. This is inaccurate, as, in reality, hospitals are very much dependent on external resources as well.

It is important that when assessing the safety level of a hospital, all factors of safety must be considered, which include both internal and external factors. The "Hospital Safety Index Guide for Evaluators" developed by the World Health Organization (WHO) and the Pan American Health Organization (PAHO) consists of 151 factors which fall under the three factors of structural safety, nonstructural safety and emergency and disaster management. However, the guide was initially developed to suit Latin American countries, which mainly experience natural hazards such as high winds, and earthquakes. This differs from Sri Lanka, which mainly experiences natural hazards such as landslides, floods and to a lesser extent, tsunamis

[210], [211]. The social context of the country is also different from the social context in Sri Lanka.

Hence, before using the WHO guide to assess hospitals in Sri Lanka, it is important to study the guide and improve it so that it is appropriate to assess hospitals in Sri Lanka.

This paper has two main objectives. The first is to define a "Safe Hospital" considering state-owned hospitals in the country and its social context. The second objective is to analyze the suitability of the "Hospital Safety Index (HSI) Guide" in assessing state-owned hospitals in the country and identify any variations that can be made in the guide to improve it. This objective will be done using case studies conducted in two Sri Lankan governmental hospitals. This paper will, therefore, provide insight into the safety levels of the two hospitals studied and improvements needed.

II Literature Review

When disasters occur, they not only cause harm to communities and their people, they also cost great damage to the economy as well. In 2016, natural hazards caused 342 disasters around the globe. These affected 564.4 million people and killed a total of 8733 people. The total estimate of economic damages was USD 154 billion [212].

Sri Lanka is a country which is also very vulnerable to many natural hazards and annually experiences floods and landslides. It also experienced the Indian Ocean Tsunami in 2004 which majorly affected the coastal areas in the country causing devastating damages and loss of life. The total number of deaths from the tsunami was 39,143 [213]. Sri Lanka was in the top ten in global disaster mortality in 2016, with a number of 0.98 per 100,000 people, with most of it being attributed to the occurrence of floods [212].

The occurrence of disasters and emergencies have the ability to accentuate the weak and vulnerable points in systems [214]. This will remain true for hospitals as well. Disasters will cause the demand for services in hospitals to increase. This can diminish the functionality and safety of the hospitals [215].

Hospitals need to be prepared for three kinds of disaster situations. One where the hospital and catchment community area are both affected by the disaster. The second is when only the catchment community area is affected and the last situation is where only the hospital is affected [214]. The catchment community area for a hospital is defined as the area from which the hospital attracts people requiring its services [211]. A fully resilient hospital must be prepared to face all three types of situations.

The month of May caused heavy floods in both 2016 and 2017 in the Western province districts of Colombo, Gampaha, and Kalutara. The damage caused to the healthcare systems by the floods amounted to LKR 597.2 million in 2016 and LKR 631.95 million in 2017 [216], [217]. Landslides in Kegalle in the year 2016 affected several areas including Samasarakande, Gantuna, Ambalakande, and Dotaloya, requiring the implementation and management of twenty camps supporting about 4200 people [217].

In addition to disasters caused by natural hazards, hospitals must be prepared to receive casualties due to societal hazards. During the new year of 2018, 512 people were admitted to the National Hospital, Sri Lanka due to fire-cracker related accidents and road accidents [218]. A food poisoning in Ampara saw the admission of 205 people in April 2017 [219].

According to the World Health Organization [209], a "Safe Hospital" is a "*facility whose services remain accessible and functioning with the maximum capacity, and with the same infrastructure, before, during and immediately after the impact of emergencies and disasters*". However, this cannot be described as the extent of the role of a hospital in the case of a disaster. People can have other expectations of a hospital in addition to receiving medical care, such as being a place of refuge when the community is affected by a disaster requiring evacuation. These expectations are often different in different countries and societies. And the expectations a citizen of Sri Lanka has will not be the same as those of a Latin American person. Therefore, it is important to define the term "Safe Hospital" for Sri Lanka and discuss its role during the lifecycle of a disaster.

"Hospitals represent more than 70% of public spending on health in countries" [209]. Sri Lanka is a country that offers free healthcare to all its citizens. In 2014, 3.5% of its GDP was allocated for health expenditure [220]. Hence it can be seen that the government of Sri Lanka allocates a lot of its resources on hospitals, including infrastructure, supplies, and employees.

Without a proper method of assessing the condition of a hospital, the administration cannot decide on how to allocate its funds to the hospital. In order to decide the proper distribution of funds for a hospital, the necessary developments to be

done for the hospital must first be identified. Therefore, prior identification of the weaknesses and vulnerabilities is very much essential and suitable methods of correcting such weaknesses must be identified. For this, comprehensive assessment frameworks should be developed. This must include the assessment of all parameters of structural safety, nonstructural safety and emergency and disaster management.

The HSI Guide was developed by the World Health Organization (WHO) along with the Pan American Health Organization (PAHO) to assess the safety level of hospitals in all aspects. The checklist in the guide consists of 4 modules. Module 1 looks at potential hazards that could affect the hospital and its role in emergency and disaster management. Modules 2, 3, and 4 look at structural safety, nonstructural safety, and emergency and disaster management of the hospital. The checklist given in the HSI Guide can be a most valuable tool in assessing the safety level of a hospital. However, this guide was initially developed to assess hospitals in Latin American countries. Therefore, altering the HSI Guide to suit the context of Sri Lankan Hospitals is essential.

A hospital must be prepared to face disasters and emergencies that affect people of the community as well as ones that will directly affect the hospital and its structures, infrastructure, and people. The WHO guidelines were developed so that the safety level of a hospital during both of those situations has to be investigated.

Prior work has been done in the field around the world as well as in Sri Lanka investigating the suitability and applicability of the HSI Guide. A study was carried out in the primary healthcare center (PHC) in Obrenovac, Serbia [221]. The area had been severely impacted by floods in 2014. The assessment gave a high level of safety in terms of structural, nonstructural and emergency and disaster management. The study also highlighted the fact that the differences between PHCs and hospitals necessitated a modified HSI to obtain a more accurate analysis of the hospital's safety levels.

A study has also been done in Sri Lanka in the District General Hospital in Matara which has looked at each aspect of safety [222]. The hospital which was highly affected by the 2004 Indian Ocean Tsunami, is also prone to floods arising from the nearby Nilaweli river. Although the study does give quantitative values for the safety levels of the hospital, the findings show that the safety levels are low and does not fulfill the basic requirements for disaster safety.

Initial work done by Kularatne et al. [211] in District General Hospital Gampaha gives some additional checks to be added to the Module 4 of the HSI Guide regarding emergency and disaster management in a hospital. There has also been work done by Kularatne et al. [119] in assessing the resilience level of critical infrastructure systems in hospitals through two case studies in Gampaha and Kegalle. Work has also been done by Hasalanka et al. [210] regarding extending the assessment criteria given by the HSI Guide in Module 2 for structural safety assessment to include assessment of structures against natural hazards affecting Sri Lanka such as floods and landslides.

III METHODOLOGY

A. Evaluating the Perception of "Safe Hospital" for Sri Lanka

For this, a questionnaire was developed consisting of 28 questions. The questionnaire sought an extension into the evaluating perception of the "Safe Hospital" considering the social context of Sri Lanka. The questionnaire was distributed as an online form to Sri Lankan citizens and the questions were a mix of yes or no questions, multiple choice answer questions, questions requiring marks out of 5, and questions requiring short written answers.

During the occurrence of a disaster, it is very common for most of the public to seek shelter at public institutions such as schools and temples. The questionnaire was used to derive whether hospitals in Sri Lanka are also considered as shelters during a disaster. The questions inquired into the demographics of the person, knowledge regarding emergency and disaster management knowledge and experience of the person as well as human behavior during the occurrence of a disaster or emergency.

The results of the questionnaire along with the literature review were used to evaluate the perception of a "Safe Hospital" as will be identified by a Sri Lankan citizen.

B. Pilot Study of the HSI Guide

The District General Hospital (DGH) Gampaha and the Teaching Hospital (TH) Kegalle were chosen as the sample hospitals to be evaluated. It was considered about the hazard profile, nature of the hospitals when making the selection. They are both governmental tertiary hospitals. The catchment community areas of the

hospitals were assumed to be the districts of Gampaha and Kegalle respectively. The emergency and disaster management level, nonstructural safety level and structural safety of the hospitals were evaluated using the checklist guidelines formulated under the HIS Guide

According to the evaluation guide, the checklist rating scale gives three different standards for the safety level: low, average and high. The equivalent mark was given as low=0, average=1, and high=2. The final rating for each submodule and the overall level of safety of the hospitals for structural safety, nonstructural safety and emergency and disaster management were given as a percentage [211].

Both DGH Gampaha and TH Kegalle were evaluated by several methods which included visual inspection of the hospital structural elements and architectural elements, inspection of hospital equipment and machinery, review of documentation including plans and programs at the hospital for emergency and disaster management and interviewing hospital staff including medical, administrative and supportive staff.

IV RESULTS

A. Evaluating the Perception of "Safe Hospital" for Sri Lanka

The study received forty responses to the questionnaire. Out of the responders, 93% were members of the general public and the rest of the 7% were hospital staff. The age of the responders varied with the majority (62%) being in the age category of 18-24, 35% belonging to the age category of 25-34 and 3% being in the age category of 45-54. Out of the six options given (religious institutions, schools, hospitals, universities, workspace, and home), 28% selected hospitals as their first choice of refuge and a further 15% selected hospitals as their second choice of refuge.

When considering the human behavior in a hospital during a disaster, it was calculated that during a disaster occurring outside the hospital premises, 65% of people would aid in helping the incoming patients and people to the hospital. On the other hand, if the disaster directly affects the hospital premises, a majority of people (48%) would attempt evacuation.

Considering about concerns of the general public regarding hospital safety, emergency and disaster response was the highest concern at 68%, followed by the presence of emergency exits (65%). Next most important was derived to be the presence of access routes, the safety of communication systems and safety of infrastructure systems of the hospital, all at 58%. When talking about access routes to a hospital, 93% of people know of at least 2 different routes to their nearest hospital, with 23% people knowing about more than 3 access routes.

It can be concluded from the questionnaire results and literature review, a "Safe Hospital" in Sri Lanka, in addition to being able to function during the lifecycle of a disaster, must also be able to provide refuge for people coming to the hospital during a disaster. The access routes, both within the hospital as well as between the hospital and the community should also be readily available and safe, for evacuation of people leaving the hospital as well as for patients and others coming into the hospital.

B. Pilot Study of the HSI Guide

An initial evaluation was done regarding the hazards that the DGH Gampaha and TH Kegalle and their catchment community areas experienced in the past and could possibly occur in the future. Considering DGH Gampaha, the hospital is in an area relatively free of natural hazards, although the catchment community area of the hospital is prone to floods during the south-west monsoon season. The hospital has experienced an accident when a hospital elevator underwent an electrical malfunction resulting in one fatality [223]. This occurred due to unpreparedness in internal emergency and disaster management and low resilience level of critical systems in the hospital.

Considering the TH Kegalle, it was observed that a side of the hospital was surrounded by a steep slope, which could be landslide prone. Additionally, its catchment community area annually experiences severe landslides.

After a thorough evaluation, by going through each criterion stated in the evaluation guide, the safety levels for the emergency and disaster management, nonstructural safety and structural safety of DGH Gampaha and TH Kegalle were quantified.

1) Emergency and Disaster Management

A sample calculation is shown for the submodule: Coordination of emergency and disaster management activities in Table I [211].

The safety level of each submodule was calculated using the equation. (1) [211].

TABLE I COORDINATION OF EMERGENCY AND DISASTER MANAGEMENT ACTIVITIES (1ST SUBMODULE) IN DHG GAMPAHA [4]

Check	Safety level	Relative score
(1) Hospital Emergency / Disaster Committee	Low	0
(2) Committee member responsibilities and training	Low	0
(3) Designated emergency and disaster management coordinator	Average	1
(4) Preparedness program for strengthening emergency and disaster response and recovery	Low	0
(5) Hospital incident management system	Low	0
(6) Emergency Operations Centre (EOC)	High	2
(7) Coordination mechanisms and cooperative arrangements with local emergency/disaster management agencies	Low	0
(8) Coordination mechanisms and cooperative arrangements with the health-care network	High	2
Total Score		**5**

$$Safety\ level = \frac{Total\ score}{2 \times Number\ of\ applicable\ checks} \times 100\% \quad (1)$$

Level of coordination of emergency and disaster management activities was calculated as shown below.

$$\text{Level} = \frac{5}{2 \times 8} \times 100\% = 31.25\%$$

The safety levels of each of the other submodules were calculated and then tabulated as shown below in Table II. Afterward, the overall safety levels of the emergency and disaster management level of DGH Gampaha and TH Kegalle were calculated using the individual scores of each submodule and the weightage of each of the submodules as shown in equation (2) [211].

$$Overall\ Safety\ Level = (\sum SL \times n) / N \quad (2)$$

SL = Safety level of the individual submodule

n = Number of applicable checks for the relevant submodule

N = Total number of applicable checks for the module

2) Nonstructural Safety

Table III gives an understanding of the overall level of the nonstructural safety of the DGH Gampaha and TH Kegalle.

3) Structural Safety

Table IV gives an understanding of the overall level of the structural safety of the DGH Gampaha and TH Kegalle.

TABLE II EMERGENCY AND DISASTER MANAGEMENT LEVELS

Submodule	Safety Level	
	DGH Gampaha	***TH Kegalle***
Coordination of emergency and disaster management activities	31.3%	87.5%
Hospital emergency and disaster response and recovery planning	20.0%	80.0%
Communication and information management	50.0%	87.5%
Human resources	40.0%	70.0%
Logistics and finance	75.0%	87.5%
Patient care and support services	94.4%	100.0%
Evacuation, decontamination, and security	25.0%	62.5%
Overall Safety Level	**51.3%**	**84.6%**

TABLE III NONSTRUCTURAL SAFETY LEVELS

Submodule	Safety Level	
	DGH Gampaha	***TH Kegalle***
Architectural safety	66.7%	93.3%
Infrastructure protection, access, and physical security	62.5%	62.5%
Critical systems [119]		
Electrical systems	55.0%	60.0%
Telecommunications systems	81.3%	91.7%
Water supply system	50.0%	60.0%
Fire protection system	0.0%	40.0%
Waste management systems	50.0%	100.0%
Fuel storage systems (e.g. gas, gasoline, and diesel)	33.3%	50.0%
Medical gases systems	91.7%	75.0%
Heating, ventilation, and air-conditioning (HVAC) systems	50.0%	100.0%
Equipment and supplies	75.0%	75.0%
Medical and laboratory equipment and supplies used for diagnosis and treatment	86.1%	88.9%
Overall Safety Level	**63.9%**	**79.5%**

TABLE IV STRUCTURAL SAFETY LEVELS

Check	Safety Level	
	DGH Gampaha	***TH Kegalle***
Prior events affecting hospital safety		
Prior major structural damage or failure of the hospital building(s)	High	High
Hospital built and/or repaired using current safety standards	Average	Average
Effect of remodeling or modification on the structural behavior of the hospital	Average	High
Building integrity		
Structural system design	Low	High
Condition of the building	Average	High
Condition of the construction materials	Average	High
Interaction of nonstructural elements with the structure	Low	High
Proximity of buildings (for earthquake-induced pounding)	High	High
Proximity of buildings (wind tunnel effect and fire)	High	High
Structural redundancy	Low	Low
Structural detailing, including connections	Low	Low
Ratio of column strength to beam strength	Low	Low
Safety of foundations	Low	Low
Irregularities in building structure plan (rigidity, mass, resistance)	High	High
Irregularities in elevation of buildings	High	High
Irregularities in height of stories	High	High
Structural integrity of roofs	Average	Average
Overall Safety Level	**55.1%**	**74.5%**

V DISCUSSION

A. Analysis of DGH Gampaha and TH Kegalle and Their Safety Levels

The following gives a discussion on the results of the assessment of DGH Gampaha and TH Kegalle.

1) *Emergency and Disaster Management*

The emergency and disaster level of DGH Gampaha is much less, at an overall safety level of 51.3% than TH Kegalle which has an overall safety level of 84.6%. When carrying out the investigation, the emergency and disaster planning of TH Kegalle was observed to be much better than that of DGH Gampaha. Unlike in DGH Gampaha, TH Kegalle had updated emergency and disaster management related plans including disaster response plan, hazard-specific plans, and evacuation plan. However, it must be noted that these planning mostly considered only situations where the catchment community area will be affected and not situations where the hospital will be directly affected.

The highest domain for both hospitals was the "patient care and support services", with safety values of 94.4% and 100% for DGH Gampaha and TH Kegalle respectively. Looking at the results of the study, it can be seen that the high scores are mainly gained for instances where disasters or emergencies affect the catchment community areas. Traditionally, hospitals have always been prepared to provide service to emergency and disaster situations in the community ranging from road accidents to mass epidemics to natural hazards.

2) Nonstructural Safety

The safety level of nonstructural parameters in DGH Gampaha is 63.9% and is less than that of TH Kegalle which has an overall safety level of 79.5%. The architectural safety level of DGH Gampaha is worse than that of TH Kegalle. The safety level of "infrastructure protection, access, and physical security" is at an equal level in both hospitals, although they both need more improvement. The safety levels of "equipment and supplies" and "medical and laboratory equipment and supplies used for diagnosis and treatment" are at good levels for both hospitals.

When looking at the critical systems and their safety levels, it can be seen that for both hospitals, the safety levels the fire protection systems are the lowest. During the investigation, it was observed that in both hospitals, there is a lack of training for hospital staff in fire hazard management as well as a lack in updating and maintenance of fire hazard management equipment such as fire extinguishers and fire hose reels

3) Structural Safety

The overall structural safety level of DGH Gampaha is 57.1% and is less than that of TH Kegalle, which has a value of 76.5%. the difference between the structural safety levels of the two hospitals could be attributed to their planning, construction, and maintenance. The DGH Gampaha consists of a series of single storied and two-storied buildings which were built since in the early 1930s for residential use and an

eight-story building which was completed in 2000. On the other hand, the TH Kegalle has a master plan which was conceptualized and designed explicitly before construction.

The investigation of the structural safety of the hospital mainly depended on visual examination and perusing structural design documents. However, not a single structural design nor drawing was found. The lack of information meant that certain checks had to be marked as "low" as stated by the WHO guide in the case of lack of documents.

B. Adjustments Developed for the HSI Guide

Additional checks that could be included in the 40 items to assess the emergency and disaster management level and in the 93 items to assess the nonstructural safety level of hospitals were developed to suit the context of hospitals in Sri Lanka.

1) Emergency and Disaster Management

In [211], 6 major additional criteria that can be added to suit for hospitals in Sri Lanka have been developed. They can be summarized as follows.

- Presence of a Hospital Disaster Management Unit
- Coordination mechanisms with hospital security personnel
- Conduction of regular and inclusive emergency and disaster management programs and drills for hospital staff.
- Use of computer systems to manage patient information.
- Presence of an official designated safe space to gather in the hospital during a disaster/emergency for hospital staff and other people.
- Presence of exit signs and location maps in the hospital.

2) Nonstructural Safety

Under the first submodule of nonstructural safety, "architectural safety", there are two additional checks that can be added. The first check is the level of visibility in the medical wards. In a medical ward, which can host a number of patients at a time, it is important that all the patients are visible to the medical officer/s in the ward in order to ensure that in case a patient is in distress, the medical staff can identify the patient and help quickly. When there are obstacles such as columns blocking visibility and complex floor shapes, it can prevent good visibility and obstruct patient care.

The second check is for the availability of adequate space in critical areas of the hospital. The lack of necessary space in critical areas of the hospital such as the Intensive Care Unit (ICU) and operating theatres can cause many problems such as overcrowding in areas housing patients, improper waste disposal, and unhygienic practices.

Under the fourth submodule which is "equipment and supplies", a check for the condition and safety of delivery paths to storage rooms should be added. Sometimes, the paths which lead from the point where the store goods are unloaded to the storage rooms are narrow and have only staircases. In this case, transporting the goods from where the delivery vehicles are parked to the storage rooms can be difficult and can prove to be accident-prone during a disaster or emergency.

The additional criteria to be assessed can be summarized as follows.

- Level of visibility in the medical wards
- Availability of adequate space in the critical areas of the hospital
- Condition and safety of delivery paths to storage rooms

C. Limitations of the Study

The first part of the study in assessing the perception of a "Safe Hospital" in the Sri Lankan perspective was limited since the questionnaire was conducted online, and as such, it prevented gaining information from all types of stakeholders relevant to the study.

The study of the HSI Guide for Sri Lankan hospitals was limited to analyzing only two tertiary level hospitals. Therefore, the results of the safety levels obtained for the two hospitals cannot be used to predict the average safety level of all other state-owned hospitals in Sri Lanka.

D. Future Works

The study of the HSI Guide can be extended to other hospitals including other hospital levels such as base hospitals and divisional hospitals to identify modifications needed for the HSI Guide for each hospital level and also to identify any

other modifications that can be made for tertiary level hospital assessment.

VI CONCLUSION

A hospital is a critical infrastructure in a community and must therefore be resilient in the face of any disaster. For Sri Lankan hospitals, the occurrence of a disaster means that in addition to continuing the operation of its functions, the hospital will also need be in a safe state to host people seeking refuge from the disaster and have safe internal and external access routes within the hospital and between the hospital and the community.

The study of the two pilot studies in DGH Gampaha and TH Kegalle shows that hospitals in Sri Lanka are very much prepared to face a disaster or emergency which could occur outside the hospital premises and bring patients to the hospital. On the other hand, they're more vulnerable to face disasters that would occur within the hospital premises.

The safety level of hospitals must be evaluated in all aspects, including structural safety, nonstructural safety, and emergency and disaster management. There are a number of assessment guides developed in the world to check these aspects, of which the HSI Guide is one. It is important that these checks are done for each hospital, to assess the preparedness to face disasters and suggest any improvements that could improve the resilience of the hospital.

The HSI Guide is a very useful tool for hospitals to identify their strong and weak points. They can thereby correct those weaknesses and improve their safety levels, thus preventing or mitigating potential negative incidents. However, the checklist is quite long, and the assessment will take a long period of time, depending on the size of the hospital. It also requires the aid of various professionals such as structural engineering experts, utility service maintenance officers, and administrative staff. To be successful, this assessment should not be a one-time activity, but a continuous process. It can be advised that this framework is implemented in a hospital by the hospital's Disaster Management Unit, or in its absence, by the Quality Management Unit and the Planning Unit of the Hospital.

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CONCEPTUAL COMPILATION OF ACTIVITY CRITERIA DURING THE POST-DISASTER STAGE OF A FIRE HAZARD IN HOSPITALS

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Abstract: The occurrence of fire hazards can cause disastrous consequences in any place and such consequences can be particularly severe in hospitals where a large number of the present population are highly vulnerable in disastrous events. It is also possible that, even after the fire hazard is neutralized, the hospital may remain in a risky position. For example, damages caused due to the electricity framework in the building can cause cascading effects later on by disrupting the power supply of the hospital. Therefore, it is important to seriously consider and undertake the necessary post-disaster activities after a fire. This paper tries to look at all activities necessary to effectively completely get through the post-disaster stage of a fire-hazard in a hospital so that it can build up its resilience to future fire hazards. This compilation of activities will include post-disaster inspection and cause identification, transfer of patients if necessary and the involvement of insurance agencies. A comprehensive list of activities has been produced separated under five categories of people, buildings and critical infrastructure systems, equipment, hospital material stores, and post-fire administrative and managerial work. Here, it is also discussed which of these activities should be applied to a scenario depending on the impact level of the fire hazard.

Keywords: fire hazards; post-disaster stage; disaster recovery; hospital safety

1. Introduction

Fires have the propensity to reach an uncontrollable stage very quickly and in its uncontrollable stage can have very disastrous effects on everything it touches. According to the 2004 World Health Report, approximately 312,000 deaths due to fire have been recorded in 2002 [7]. Smoke, which is a bi-product of fire, is equally as dangerous, as it includes narcotic gases such as carbon dioxide, carbon monoxide, and hydrogen cyanide, irritants like nitrogen monoxide, nitrogen dioxide, ammonia, hydrogen fluoride, hydrogen bromide, Sulphur dioxide and hydrogen chloride, volatile organic compounds such as isocyanates, phenol and styrene and carcinogenic compounds such as benzene, polycyclic aromatic hydrocarbons and dioxins [8]. In addition to the deaths, fires have also caused around 11,471,000 recorded cases of diseases in 2002.

Even in institutions as respected and trusted as hospitals, fire disasters can occur, causing damage to people, buildings, critical infrastructures such as electrical systems and fuel supply,

hospital equipment and medical stocks. The likelihood of a fire occurring in a building can vary with the functions occurring in the building [56]. Therein, it can be deduced that hospitals run a high risk of fires occurring in their buildings as they contain substantial quantities of combustible material such as flammable chemicals and medical gases, electrical generators and large networks of electrical wiring. This can be evidenced by past fire disasters that occurred in hospitals around the globe. The 2008 fire in the Royal Marsden Hospital in London caused the entire hospital to be evacuated from the buildings and also caused damage worth 500 million Great British Pounds [93]. The 2011 hospital fire in AMRI hospital in Calcutta, India caused 89 deaths [60], [61] while in 2013, the fire in the Ramenskyon Psychiatric Hospital in Moscow, Russia caused 38 deaths [62]. A fire in 2018 in the Sejong Hospital in South Korea caused 37 deaths, mainly from smoke inhalation and caused another 130 persons to be injured [224].

With the introduction of frameworks such as the Hyogo Framework in 2005 and its successor, the Sendai Framework in 2015, many institutions including hospitals, have come to understand the need for concepts such as Disaster Risk Reduction (DRR) and Build Back Better (BBB) [128]. As such, hospitals globally, have begun to operate programs such as risk assessments of the hospital, disaster training of hospital staff and disaster and emergency management [10], [12], [23], [130]. Disaster management can't be described as a linear process as it is continuous and therefore can be depicted as a cyclic process consisting of the phases prevention, preparedness, response, mitigation and recovery [131].

When dealing with DRR, it is necessary to give equal importance to the recovery process. When hazards occur, it is not always possible to prevent disastrous results affecting the community. Therefore, being prepared to take the necessary action after the disaster is mitigated is also a significant part of the DRR process.

When specifically considering fire disasters in hospitals, it can be clearly reasoned that the extinguishment of the fire will not end the work that is needed to be done to prevent more loss and damage to the hospital. This study seeks to compile a list of post-disaster activities that need to be conducted after a fire has occurred in a hospital in order to Build Back Better.

2. Post-Disaster Frameworks

A disaster is most often a sudden and unforeseen event, which overwhelms local capacity and requires external assistance. These events can cause significant damage, destruction and human suffering (Global Facility for Disaster Reduction and Recovery (GFDRR), 2015). Administrators often find that working to recover from a disaster can be a challenge, as there is much greater pressure on them than during a non-disaster period. This is due to factors such as the need for rapid reaction and quick results, media attention, and the involvement of external stakeholders such as local and international aid agencies. This pressure can be increased when there is also a lack of experience and capacity in handling the work amount necessary [131]. Complete recovery from the disaster will include restoration of not only the physical structures but also the social stability of the affected community. Recovery after a disaster includes a large range of activities and these work for recovery and coordination can be categorized into the following modules; Institutional arrangements for recovery, Post-disaster needs assessment, Recovery planning, Managing recovery, Building Back Better and managing residual risks and Resource mobilization [131].

It is understandable that the method of disaster recovery can vary considering the factors relevant to each disaster, such as the type of disaster, its impacted population and the significance of the damage on persons and properties. The guide to developing disaster recovery frameworks published by the GFDRR has its own separate modules that can be customized to suit the needs of the target audience. These six modules can be named as follows: Conducting post-disaster damage and needs assessment, Policy, and strategy-setting

for recovery, Institutional framework for recovery, Financing for recovery, Implementation arrangements and recovery management, and Strengthening recovery systems in governance (GFDRR, 2015).

The recovery plan which would be successful in the long term would be a plan where the divisions of Finance, Regulation, and Administration work cohesively and concurrently so that all financial, technical and human resources available can be used for recovery, reconstruction and risk management.

It is evident from historical incidents that disasters affect poverty-stricken families much more harshly, effectively paralyzing the production and income of families. In such a case, it is important that low-income victims of disasters are compensated fairly, considering both their injuries and losses as well as their predictable future losses due to the disaster. A major requirement here is ensuring the victims' job stability [144].

Vulnerability to disasters increases due to the weak environment and weak disaster management [145]. In order to build back better, it is important to not just restore the status of the institution to the pre-disaster state but to improve further. An institution's disaster management plan should not be allowed to stagnate but should be constantly improved, by taking lessons from past disasters [23].

According to the Disaster Preparedness and Response Division, Ministry of Health of Sri Lanka, there are several key indicators of the recovery plans of the health sector (Ministry of National Policies and Economic Affairs and Ministry of Disaster Management, 2017). They are as follows.

a. The hospital being repaired and functional to their full capacities
b. Reconstruction of hospital structures incorporating disaster resilient features and following the Safe Hospital guideline given by the WHO and PAHO
c. Preparedness of healthcare systems to respond to disasters
d. Having conducted disaster drills
e. Number of households being covered under health insurance schemes

Post-disaster recovery planning means the development of a number of strategies to bring back the community or institution to where it was before the disaster and continue further to improve its state. These strategies can include the development and implementation of the following; Post-disaster recovery plan, Recovery ordinances, Continuity plan, Post-disaster buildable lands inventories, Utility recovery and reconstruction plans, Temporary shelter plan and Establishment of a coordinating organization and guiding principles for reconstruction [146].

There have been defined Standard Operating Procedures (SOPs) for hospitals themselves regarding emergency and disaster management. It can be seen in these guidelines, that hospitals must be concerned with external disasters occurring outside the hospital in the community as well as disasters that may occur within the hospital [147], [148]. The guidelines themselves are mostly concerned with the preparedness for disasters in hospital and are less descriptive regarding the recovery stage and the activities to be done. However, post-disaster follow-up and critique of actions during disasters have been mentioned to be a critical path of disaster management in hospitals [149]. This includes event analysis and incident reporting [138]. There are three main goals regarding protection from fire in hospitals; safety of life, protection of property, and continuous operation of the facility [138]. Disaster management in hospitals, which are institutions with already complex work, becomes even more complex [150]. Therefore, the actions taken must be careful, thorough and well-planned.

3. Methodology

The aim of this study was to develop a compilation of activities that can be proposed for a post-disaster situation after a fire has occurred in a hospital. As part of the study, fire safety and management in nine governmental hospitals in Sri Lanka were studied. These hospitals included various tiers of government hospitals in the country, starting from Tertiary hospitals such as District General hospitals and Teaching hospitals to Secondary hospitals such as Base hospitals and Divisional hospitals and Primary medical care units.

In considering the post-disaster stage of a hospital in the case of a fire hazards, the following factors were identified through the hospital survey.

a. Aspects of hospitals that could suffer losses from fire hazards such as patients and staff, equipment and infrastructure.
b. Essential areas of management in a post-disaster situation in a hospital such as patient handling and patient care.
c. Stages of a fire hazard in a hospital and probable effects in the hospital from each level of hazard.
d. Short-term and long-term effects from a fire hazard in a hospital

Along with the exposure gained through these surveys, a thorough literature review and peer discussions were done to compile a comprehensive and thorough list.

In this compilation, the categorization of activities was partially adopted from the Hospital Safety Index (HSI) Guide [23], where the major modules are structural safety, non-structural safety, and emergency and disaster management. The categorization for the activity list for post-disaster fire situation was done as follows.

1. People
2. Buildings and critical infrastructure systems
3. Equipment
4. Hospital material stores
5. Post-fire managerial and administrative work

It was also deduced that the number and type of activities would differ according to the impact and magnitude of the fire. Therefore, the next part of the study included analyzing how to assign the activities according to the impact of the fire and the aspects of the hospital which could be affected by the fire.

4. Compilation of Proposed Post-Disaster Activities After a Fire in a Hospital

As mentioned earlier, fires in hospitals can leave devastating results, and after the fire is extinguished, there remains a number of actions that must be taken, in order, to first, prevent damage that has occurred from spreading further. Next, action must be taken so that the recovery of the hospital is efficient and comprehensive, where the concept of Build Back Better (BBB) is fully adopted.

A disaster such as a fire can affect various aspects of the hospital. We can categorize the aspects that be affected into four major areas; people, buildings and critical infrastructure systems, equipment and material stocks. in the compilation of the activity list, each of these four aspects has been considered and activities that will be needed for each aspect of the hospital have been described.

4.1 People

When considering the people in hospitals, it must be realized that there are various types of people within a hospital. They include hospital patients, patient' visitors and hospital staff such

as medical staff, supportive staff, administrative staff, and external service providers [10], [12]. After the fire, it is important that all persons who were in the fire-affected area are given a thorough medical examination, including those who do not show any physical trauma. This is because, in the occurrence of a fire, in addition to being burned, a person can be negatively impacted due to the bi-products of fire such as smoke and soot [206]. After the fire, it is important to confirm the safety of the affected area and do necessary investigation and cleanup before letting people come back into the buildings. Sometimes, the evacuated persons will have to be moved to another building in the area, or to another hospital entirely. In any case, there should be arranged a place of shelter where the evacuated persons can stay until a permanent arrangement is made. As there could be a need for hospital patients and victims of the fire to be transferred to another hospital, transportation systems such as ambulances from the hospital should be prepared to be used if necessary.

During the initial medical examination, the affected persons will be identified. After providing emergency medical care, the victims of the fire must be admitted for further medical care. This could be done in the same hospital if possible, or in the next nearest hospital that can provide sufficient medical care. Similarly, any hospital patients who were evacuated during the fire should be similarly transferred to another area of the hospital, which was unaffected by the fire, or to the nearest hospital which can fulfill the medical requirements of the patients.

A large disaster can cause a situation where there will be people missing after the fire. In this case, first, a list of all people missing must be compiled by the hospital administration staff in cooperation with relevant authorities such as the police force and the firefighting department. Search operations for the missing persons should be arranged and conducted.

In some cases, victims may be found deceased. In this case, usually, most countries' police force or other relevant authorities have a process of action that must be taken. In general, the following work must be done; the deceased victims should be identified, if possible, and after possible investigation on the site of the fire has been concluded, the deceased victim must then be transferred to an examination area to perform an autopsy. After the investigative and medical work has been concluded, the body may be released to the deceased's family [207].

Another action that must be taken is to recruit staff in order to replace any staff member who might have been affected by the fire and will be needing some recuperating time [23].

Finally, there is some long-term recovery-related work that needs to be done, for the people who were affected by the fire as well as for their families. In addition to suffering from injuries and loss of property, they may also suffer from loss of income revenue due to the losses incurred. Therefore, it is necessary that the hospital provide compensation to the victim or the victim's family. For the fire-impacted persons, who are seeking to claim from personal insurance policies, the hospital should be efficient in arranging the necessary documentation for the insurance companies. Finally, as to ascertain the wellness of the affected populations' emotional stability, the hospital should arrange and offer counseling for the people.

4.2 Buildings and Critical Infrastructure Systems

As mentioned before, it is unwise to enter the fire-affected buildings immediately after the fire has been extinguished. The buildings that were affected directly by the fire as well as indirectly through the bi-products of fire like smoke should be given an initial check to confirm whether the area is safe to be entered. This should be done by a trained professional such as a firefighter. The critical infrastructure systems in the affected area should also be checked to ensure that the extinguished fire would not cause cascading disasters through the systems. These systems will include electrical, water supply, medical gas, fuel supply, heating, ventilation, and air conditioning, waste management and elevator systems. Another action that must be taken is

to clear the paths and routes within the hospital that may have been blocked during the fire, so that patient translocations that are needed can be done easily and safely.

In case of severe damage, the next step is to contact the insurance agency of the hospital. This step is to be taken if the hospital has been insured. The damages in the affected area must be assessed by the responsible authorities such as the insurance agents, firefighters, and police officers. The assessed damages must thus be documented. After the assessment and documentation have been completed by all parties responsible, the affected area should be thoroughly cleaned up, which will include the toxic products that will have been left by the fire, like toxic gases, smoke, and soot.

Before the fire-affected area of the hospital can rebegin to operate, the necessary retrofitting and reparation of damages can be done. This should be planned methodically and thoroughly.

During the fire, fire detectors and fire alarms, firefighting equipment such as sprinkler systems and fire hose reels and portable fire extinguishers could have been used. Afterward, the hospital should take care to replace any fire extinguishers used. Also, all the systems including fire detection and alarms and sprinkler systems should be assessed and any damage incurred should be repaired as soon as possible.

4.3 Hospital Equipment

Hospitals have many kinds of equipment, including medical equipment, laboratory equipment and other equipment such as kitchen equipment. If the fire-affected area has any type of equipment present, certain steps should be taken. First, equipment in the area should be checked to see if any damage has been incurred during the fire. If so, the hospital must contact the insurance agency if the equipment has been insured.

The damage to the equipment should be assessed and documented and necessary reparations or replacements of the equipment should be done.

4.4 Hospital Material Stores

Hospitals are required to have storage spaces for various items. Usually, there are general supply stores, medical stores, surgical equipment stores, blood banks and other miscellaneous item stores (recycle items storage, kitchen supply storage, etc). In the occurrence of these storage spaces being affected by the fire, the following actions must be taken. An initial check must be carried out to assess if any serious damage has been caused by the fire. If the damaged store items have been insured, the insurance agency must be contacted and notified. Then the damage should be assessed and documented and finally, the stores must be restocked if needed.

4.5 Post-Fire Managerial and Administrative Work

It is important, that after any type of disaster, the administration takes action so that the institution is not only restored to its pre-disaster status but improved even further. Here, the paper discusses the summary of the actions that the hospital's administrative division should take so that in the future, the hospital's resilience is increased through principles of Build Back Better (BBB).

As soon as possible after the fire is extinguished, the fire-affected areas must be secured until the investigative and restorative work is completed. The police force must be contacted, and the cause of fire should be investigated.

Working with media institutions is an important part of post-disaster recovery. In order to prevent the propagation of misinformation and unnecessary panic, it is important that the administration of the hospital prepare and present a statement regarding the fire disaster to the media at the earliest possible time.

Another important factor is the continuity of the administrative work after the fire. In case the fire caused administrative office facilities to be affected, temporary office facilities should be arranged until restorative work is completed.

A vital element of post-disaster activities is the Disaster Recovery Plan (DRP). The administration should prepare a customized DRP, put it into operation and monitor and evaluate the outcomes. After a disaster, institutions have to be prepared to manage donations and other kinds of funding that will come through to the institution. The management of the funding flow should also be included in the disaster recovery plan.

The next significant item of action is the updating of the hospital disaster management plan. In order to BBB and increase resilience, it is important that the disaster management plan is updated from the "Lessons Learnt" from the past disasters that occurred. It is therefore important to review the actions of the hospital staff during the fire and analyze the weaknesses of the current action plan. Thereby, the hospital disaster management plan can be reviewed and modified to better suit the institution.

4.6 Summarization of the Proposed Activity List

The developed list of proposed activities to be conducted after a fire disaster occurs in a hospital is has been summarized in tabulated form in Table 1.

Table 1 Proposed post-disaster activities to be conducted in a hospital after a fire

People	Building and Critical Infrastructure Systems
A 3. Provide medical attention to all persons who were in the affected area 4. Provide a shelter space for all persons who were evacuated from the affected area **B** 4. Arrange transportation systems such as ambulances in preparation to transfer patients **C** 5. Admit the victims affected by the disaster c. To the same hospital if suitable d. To the next hospital which fulfils the medical requirements of the patients **D** 6. Transfer the evacuated patients a. To an unaffected part of the hospital if suitable b. To the nearest hospital which fulfils the medical requirements of the patients **E** 9. Provide compensation to victims affected by the fire or the victims' families 10. Provide validating documentation for victims claiming personal insurance 11. Arrange counselling for disaster victims **F** 11. Identify missing persons 12. Arrange search operations for missing persons **G** 12. When a victim is found diseased	**I** 4. Conduct initial check by trained professionals to confirm whether the area is safe to enter 5. Conduct check of infrastructure systems to confirm operational capability a. Electrical systems b. Water supply systems c. Medical gas supply d. Fuel supply e. HVAC system f. Waste management systems g. Elevator systems 6. Clearing paths and routes within the hospital **J** 6. Contact hospital insurance company 7. Assess damages and document the damages **K** 9. Clean area affected by the fire and dispose of toxic products of the fire **L** 10. Retrofitting and reparation of damages in the affected area **M**

<table>
<tr><td>a. Identify victims (If possible, through visual inspection)
b. Conduct onsite examination of the body
c. Transfer the body to an examination area
d. Perform autopsy
e. Release body to victims' families
H
13. Mobilization and recruitment of new hospital staff</td><td>11. Restock the equipment used for fire fighting</td></tr>
<tr><td>Hospital Equipment</td><td>Hospital Material Stores</td></tr>
<tr><td>N
2. Initial check to see whether the equipment is damaged or safe to use
O
5. Contact insurance company
6. Assess the damage of the equipment
7. Reparation or replacement of damaged equipment</td><td>P
4. Contact insurance company
5. Assessment of damage
6. Restock stores if needed</td></tr>
<tr><td colspan="2">Post-Fire Managerial and Administrative Work</td></tr>
<tr><td colspan="2">8. Secure the areas affected by the fire until restoration is completed
9. Contact Police and start the investigation of the fire and its cause of origin
10. Prepare and present a statement regarding the disaster event to the media
11. Provide temporary office facilities in case administrative buildings are affected
12. Disaster Recovery Plan
a. Prepare plan
b. Operate the plan
c. Monitor and evaluate outcomes
13. Hospital Disaster Management Plan
a. Review hospital actions during the fire
b. Deduce weaknesses in the current plan of action
c. Review the plan of action during a disaster and modify
14. Manage funding and donations given for reparations</td></tr>
</table>

5. Discussion

Although the compiled list of activities is vast and comprehensive, it must be realized that not all of the activities will be needed to be done in each and every occurrence of a fire hazard. As we can see in Fig. 1, the area affected by fire can depend on the time taken to stop the fire. With the level of impact, the impacted aspects of the healthcare institution can vary.

A fire can be extinguished almost immediately after it starts, resulting in no losses being incurred on any people, buildings or equipment. There can be some instances, where no people are harmed, but the equipment is severely damaged. There can also be instances where a large portion of the hospital is damaged, meaning there are losses incurred in all aspects of the hospital.

In Fig. 1, Fig. 2, Fig. 3, and Fig. 4, it has been identified how the activities needed to be done after varying levels of impacts of fire can be chosen from the list that has been compiled.

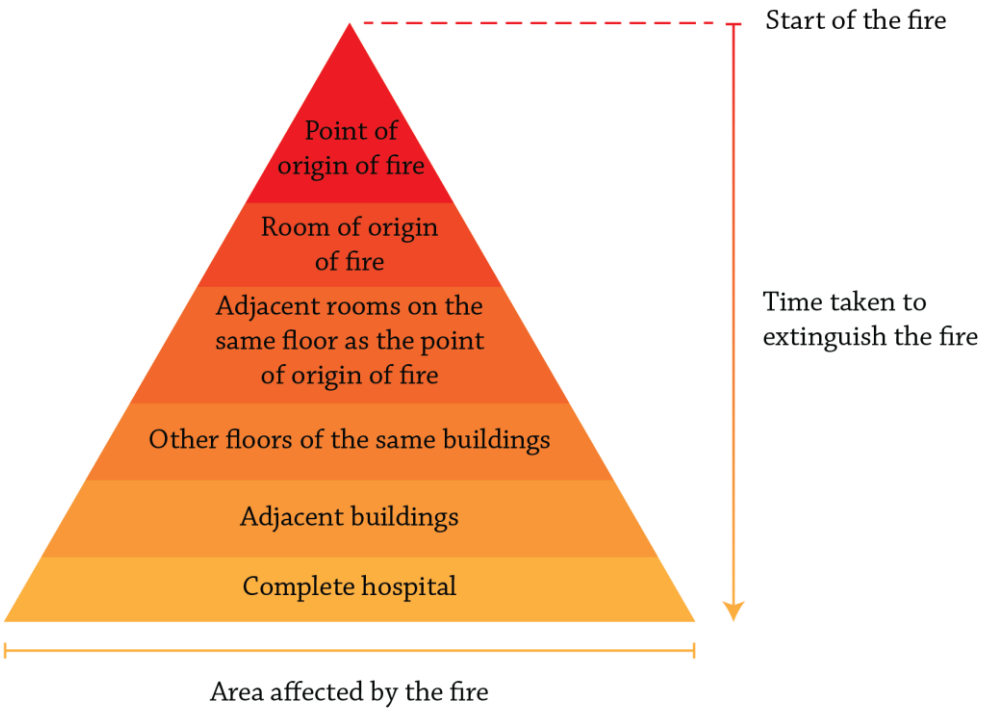

Fig. 1 Variation of the impact of fire with time

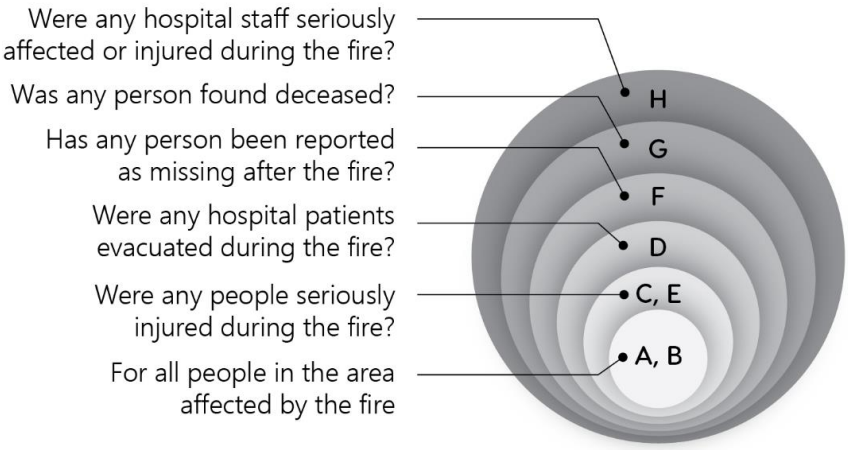

Fig. 2 Activity categorization according to the level of impact on people

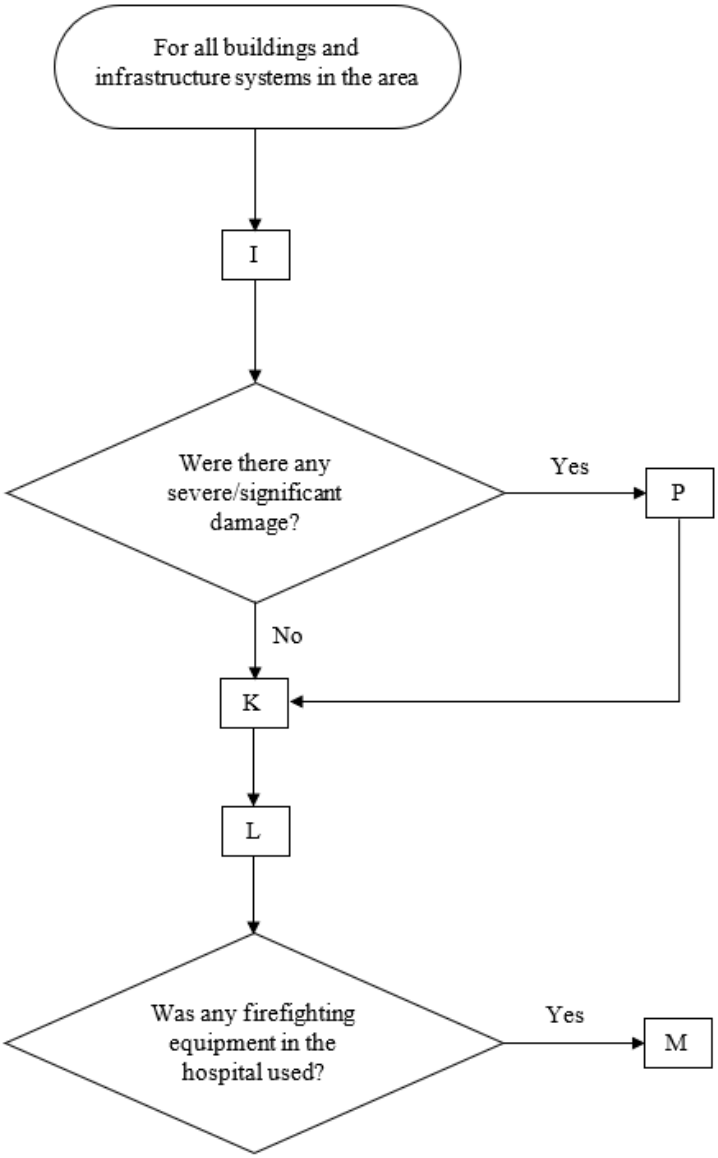

Fig. 3 Activity sequence for buildings and critical infrastructure in the fire-affected area

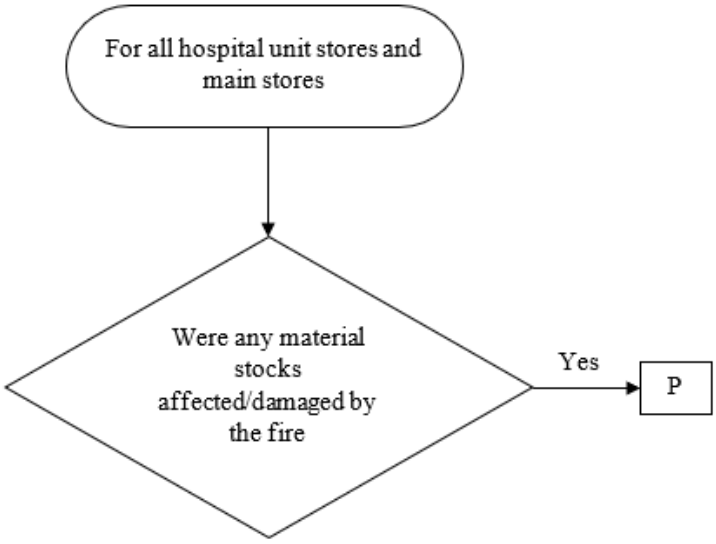

Fig. 4 Activity sequence for material stores in the fire-affected area

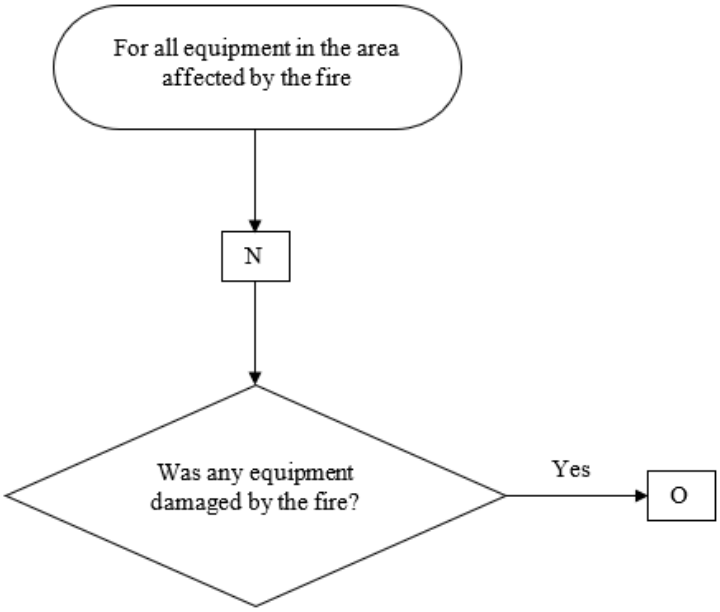

Fig. 5 Activity sequence for equipment in the fire-affected area

6. Conclusion

Fire hazards, unlike natural hazards, can be prevented from occurring, through good practices of fire safety and fire risk management. An aspect of good fire risk management is incorporating lessons learned into the overall risk management plan.

However, there will be instances wherein spite of all precautions, a fire can occur in a hospital, causing the need for post-disaster action to be taken. Therefore, the presence of an action plan for post-disaster recovery is necessary, especially for a large institution such as a hospital.

The aspects that be affected by a fire hazard in a hospital include people, buildings and critical infrastructure systems, equipment and material stores. These effects can be short-term or long-term and therefore, the hospital administration must be prepared to deal with both kinds of effects. In addition to handling the negative effects on these aspects, the hospital will need to deal with other stressful activities such as communication with media and recovery fund raising work. As mentioned in literature regarding post-disaster frameworks, recovery planning is an important aspect in disaster recovery. When a healthcare institution has a prepared basic recovery plan ready at the time of the disaster, the recovery planning phase in the post-disaster stage can be completed quickly and recovery can be accelerated.

It must be noted that the results of each fire hazard can be different and therefore, the recovery plan for each hazard must also be different. With this developed list of criteria, it is hoped that healthcare systems can use the list as a foundation on which to build a comprehensive and customized criteria list according to the nature and scale of the fire hazard that has occurred.

This study is part of a larger project in building a fire risk management framework for hospitals for the Sri Lankan aspect. The next step in this study is to validate this compiled list of activities through an expert opinion survey.

Acknowledgment

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Appendix X : Conference Paper, International Conference on Sustainable Built Environment, December 2020

Investigating the Preparedness of Staff Members in Privately Owned Hospitals in Sri Lanka against Fire Hazards

Abstract:

Purpose - Hospitals have a high potential for fire hazards due to reasons such as the presence of volatile chemicals, large electrical networks, and high waste generation. In addition to taking steps to prevent fire, preparation of staff to face a fire hazard should also be done. This study looks at the current level of fire safety training and preparedness of staff members in privately owned hospitals in Sri Lanka.

Design/methodology/approach – A structured questionnaire was developed to assess fire safety training and preparedness of hospital staff members. This was used to interview sixty-six staff members of multiple major private hospitals. The staff consisted of various positions ranging from medical staff to security and maintenance staff.

Findings - The study revealed that over 70% of the staff had training in basic fire management and more responsibility in emergency response had been given to the maintenance and security staff in the hospitals. Overall, the staff in private hospitals were suitably prepared for fire hazards, with each institution holding fire training programs annually. It is recommended that staff preparedness can be increased through actions such as carrying out regular fire safety training and drills, developing a fire action plan for the hospital, and designating a fire safety officer for the hospital.

Originality – This paper identifies the preparedness of staff in privately owned hospitals in Sri Lanka in case of a fire and the actions needed to further improve the level of preparedness.

Keywords:

Fire hazards, safe hospitals, disaster risk reduction, fire safety training

1. Introduction

Fire hazards, which could originate from within buildings, or as wildfires have the potential to cause serious injuries and even death [6], [7]. Smoke, which is the byproduct of fire also contributes to 1% of the diseases around the world [38], [39]. In addition, fires can lead to psychological stress and property loss [225]. In the 21st century, the world experiences 7 to 8 million fires annually, resulting in over 500,000 injuries and around 300,000 deaths (Brushlinsky et al., 2006; WHO, 2004). In Sri Lanka also, fires account for 5% of recorded disaster events in the country [24].

The risk of a fire occurring in a building can depend on the characteristics of the building such as height, structure and diverse function as well as the nature of ignition sources which may be present in the building and their quantities [56], [57]. When looking at the routine functions of a hospital, it can be considered that hospitals have potential risk for fires. For example, hospitals have a large number of medical equipment that draws a high amount of electricity, which paves an easy path for electric fires from electric overloading [59]. Again, hospitals normally use medical gas supply lines that run throughout the hospital buildings, which means that hospitals have a high concentration of oxygen gas [67]. Hospitals also have large quantities of flammable or combustible material in storage, such as highly concentrated

medical solutions and alcohol-based solutions. Finally, hospitals have a large, daily waste generation.

The impact on people's lives due to a fire in a hospital can be high due to the type of population present in the hospital, with many patients having mobility issues. Evacuating people who are able-bodied during an emergency is still a difficult task, due to the panic that would set in as well as the traffic that would be created in escape corridors and stairwells. When the majority of people in the building have mobility issues, the evacuation process is made much harder. A recent study has identified several hospital units as critical units, as they hold the most vulnerable patients who cannot be easily evacuated. These identified units are maternity units, labor rooms, premature baby units, neonatal intensive care units, intensive care units, operating theatres, and pediatric units [51].

The risk of fire in hospitals can be seen more clearly by looking at past incidents. The AMRI hospital in Calcutta, India experienced a fire caused by a short circuit in 2011 which caused 89 deaths [60], [61]. Another fire hazard in the Ramenskyon Psychiatric Hospital in Moscow, Russia in 2013 was caused by a smoking incident and resulted in 38 deaths [62]. The fire hazard in the Royal Marsden Hospital in England in 2008 caused damages worth GBP 500 million at the time [63].

The risk of fires is equally present in hospitals in Sri Lanka as well. The Anuradhapura Teaching Hospital experienced a fire in 2014 when an MRI Scan machine was being installed. The destroyed machine was worth an equivalent of USD 1.9 million at the time [64]. In early April of 2020, there was a chemical fire at the pharmaceutical storage facility of the Teaching Hospital Kurunegala which destroyed medical supplies stored in three rooms as well the ground floor corridor of the facility [47].

Considering the above-mentioned factors and the high risk of fires in hospitals, fire safety management should be an integral part of the hospital strategy to be a "Safe Hospital". In fire safety management, the concepts of fire prevention and protection from fire should both be adopted [57]. Staff preparedness is a significant part of fire safety management.

The positive effect that fire safety training can have during a fire incident as well as the negative impact due to a lack of training can be understood from the following two examples.

1. The Royal Marsden Hospital fire (2008), although it caused a high financial cost, did not experience any casualties. The fire caused the hospital to evacuate over 150 patients and 800 staff members. This impressive safety in terms of human lives was a direct effect of the excellent fire safety training given to staff members [63], [93].
2. The chemical fire at the Teaching Hospital Kurunegala (2020) had blazed when the staff had attempted to use water to douse the fire. This shows the negative impact due to the staff members not being trained on the proper suppression methods and material for different types of fires [226].

As can be seen from the two examples, a high level of fire safety training and preparedness directly impact whether the losses from a fire will be major or minor. Therefore, hospital staff members must be well versed in fire safety practices.

Sri Lanka has both government-owned hospitals as well as privately owned hospitals. In this research study, an attempt is made to analyze the fire safety training and preparedness of staff members in privately owned hospitals. The study was preceded through a literature review regarding fire safety training needed for an institution's staff.

2. Literature Review

Providing fire safety training to staff of an institution as well as conducting regular fire drills is an important part of fire risk management. In a hospital, especially, the presence of nursing staff with fire safety training is the best defense in the face of a fire [59]. A study done in Malaysia regarding preparedness and resilience in hospitals has shown that human resources and training have been ranked highest in terms of preparedness and the ability to adapt in a timely manner has been ranked highest in terms of resilience [170].

There are instances that hospitals do not consider fire hazards as a top priority, especially in highly controlled areas such as operating theatres. However, surgical fires have been ranked as the number 3 among the top 10 technology hazards [171]. Many professionals mistakenly assume that if a fire occurred in an operating theatre, then that fire was not preventable. However, most surgical fires are preventable. Preparing for a fire hazard is important in a hospital, as there will be a large population of weak and vulnerable patients who will be depending on the staff members for their safety [172]

Fire hazards have the potential to occur suddenly and without warning. They can become intense quickly, and therefore the response to fire needs to be very quickly in order to minimize the losses [173]. If staff members have not had previous training, it is not realistic to expect that they would respond to a fire in an effective way [174]. Although panic behavior is not common in the face of a fire, the lack of knowledge on the fire emergency actions as well as the induced stress can end up causing people to make fatal errors [175]. The lack of staff training in fire safety can increase confusion, which would increase the danger during the time of a fire hazard [176]. In some people, the lack of previous experience can cause the phenomenon of “cognitive paralysis”, where people end up not taking any action. This can lead to fatalities that could have been avoided [177], [178].

Fire safety training has been identified as a tool to help improve fire safety knowledge and the response to a fire. This can result in minimizing fire-related casualties [179]–[181]. Fire safety is the collective responsibility of all staff members and therefore, it is important that staff members in each department of the hospital are actively involved in fire safety training [182]. The way a person acts during a fire depends on factors such as personality and leadership abilities, decision-making styles, and the amount of fire training received [183]. Therefore, when assigning disaster and emergency duties to the staff members, the above-mentioned factors should be considered.

Fire safety drills should be used in institutions as they are effective in converting fire safety training into an experience that the staff members can use to respond effectively during a fire hazard [184]. This experience helps a person to effectively analyze the situation and correctly understand the information in the surroundings [173]. Previous studies have found that unannounced drills and exercises are often more effective [185].

An experiment done in the Netherlands shows the effectiveness of hospital staff training in an evacuation. The same evacuation procedure was practiced in two rounds for patients of different medical status. It was observed that during the second round of evacuation, the hospital staff managed to achieve a significantly better evacuation rate [66]. The results of the experiment have been illustrated as seen in Figure 1.

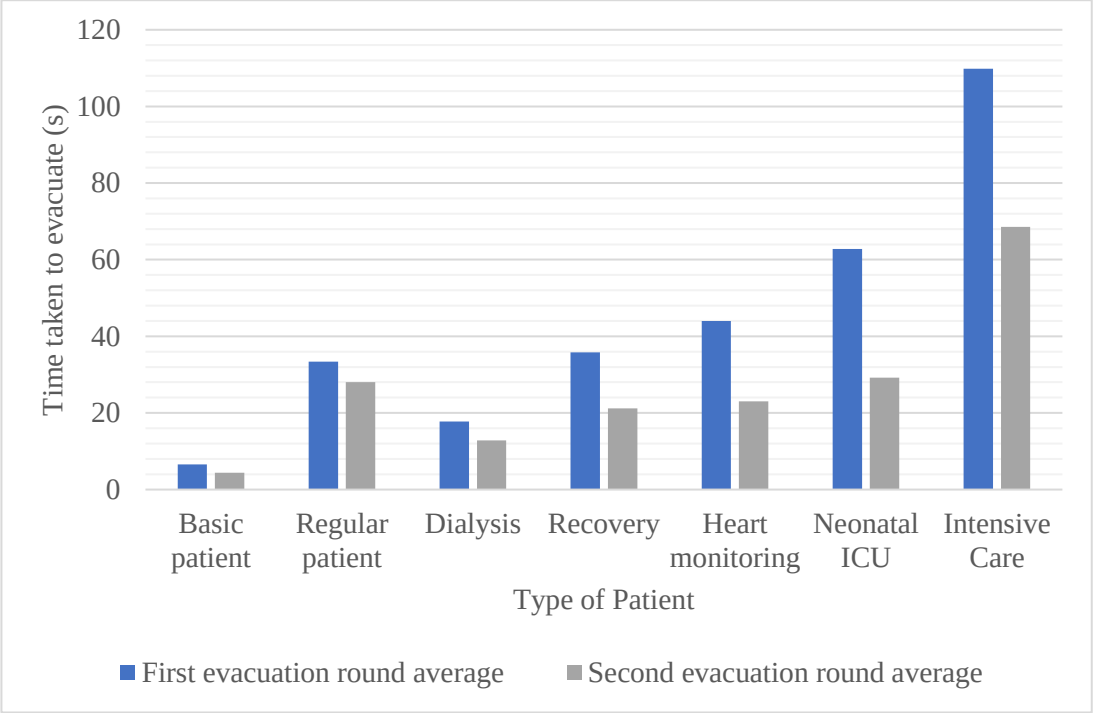

Figure 1 Influence of trained staff during evacuation [66]

The training given to an institution's staff should be customized to the characteristics of the workplace. The training should [126],

- Provide information about the emergency procedures
- Consider the duties and responsibilities of the staff
- Be understood by the staff
- Consider the results of risk assessments done for the institution

Fire training should include providing the staff members with a sufficient level of the knowledge of operating and maintaining fire safety equipment such as fire extinguishers, fire hose reels and fire blankets [186], [187]. The training should also include a description of staff duties, emergency evacuation procedures, and contacting the local fire service department [188]. It is important that the training is conducted so that the participants fully understand it and know their roles. Therefore the training should not only include a sufficient amount of time on life safety training and drills, it should also be of good quality and tailored to the participant group [189]. Fire safety training should also be conducted at regular periods, so that the staff members continuously review, revise, and reconfigure their knowledge on fire safety [190].

Fire safety preparedness should include developing and maintaining a fire safety plan. Two essential actions for fire safety in an institution is the appointment of a fire safety manager, who is responsible for the overall fire safety management, and the maintenance of a fire safety manual, which will contain all documentation regarding the fire safety planning in the institution [166].

3. Methodology

Sri Lanka has a free healthcare system for all citizens through 1100 primary, secondary, and tertiary level hospitals [227]. Privately owned hospitals, which charge for healthcare services, also operate in the country. Many recent risk assessment studies carried out regarding hospitals

in Sri Lanka have only focused on government-owned hospitals. However, when fire risk is concerned, all hospitals where government-owned or privately owned must be considered. In this study, the focus was given to fire risk preparedness of staff members on privately owned hospitals in the country.

Staff members of three major privately owned hospitals were interviewed during this study. For confidential reasons, the hospitals shall be referred to as Hospital A, Hospital B, and Hospital C in this paper. Each of the hospitals had a different administration system. Hospital A is headed by the hospital director, while Hospital B's administration is done through a Board of Directors. Hospital C is administrated by a General Manager.

3.1 Survey Development

The first part of the survey looked at the demography of the responders. The elements in the section included the job position of the responders, their gender, age category, number of years they had worked at the hospital, and previous work experience in hospitals.

The second section tested the preparedness of the responders in three different ways which were identified in the literature review: past experience with fire hazards in hospitals, training, and drills regarding fire hazards experienced in the current and previous workplaces and knowledge regarding the procedures that need to be followed during a fire hazard. The section considered activities regarding sounding the alarm, preliminary firefighting by the staff members, evacuation of self and patients and contacting the local fire service department. The final question was a self-evaluation of the responder's preparedness regarding fire hazards.

3.2 Choosing the Sample Set

3.2.1 Sampling Method

Hospitals have a large number of staff members, medical and non-medical, who have various types of duties and responsibilities. As a hospital has various areas with a high risk of fire, most staff members have a possibility of experiencing a fire hazard. Therefore, all staff members in a hospital must possess a basic level of preparedness for a fire hazard. Therefore, in this survey, a random sampling method was used, ensuring that staff members of all levels and various job titles were included in the survey.

3.2.2 Sample Size

The total population of permanent staff members in the three hospitals rounds off at 1500. Assuming a confidence level of 90% and a 10% margin of error, the ideal sample size was calculated.

For 90% confidence level

Z score = 1.65

$$\text{Sample Size} = \frac{\frac{z^2 \times p\,(1-p)}{e^2}}{1 + \frac{z^2 \times p\,(1-p)}{e^2 N}}$$

z = Z Score

p = Standard Deviation

e = Margin of Error

N = Population

The standard deviation was assumed as 0.5 in order to ensure the sample size was large enough.

$$\text{Sample size} = [1.65^2 \times 0.5 \times (1–0.5) / 0.1^2] / [1 + (1.65^2 \times 0.5 \times (1–0.5) / 0.1^2 \times 1500)]$$

$$= 65$$

3.3 Data Collection Method

Each of the responders was interviewed using the structured questionnaire. A total of 66 responses were obtained. The responses were then analyzed to find out the preparedness of the staff against a fire hazard in the hospital.

Each of the hospitals had a specific staff member who was responsible for fire safety management in the hospitals. To gain a better and overall insight into the fire safety practices of each hospital, these staff members were also separately interviewed at a greater depth.

4. Demography of the Responders

From the 66 responses that were obtained, 20 of the respondents were from Hospital A, 30 from Hospital B and 16 from Hospital C. The responders included various hospital staff members such as nursing staff, maintenance staff, security staff, office staff, storage staff, laboratory staff, and supportive staff. The distribution of the responders according to their staff position can be seen in Figure 2. A higher percentage of the responders were female with only 38% of the staff members being male.

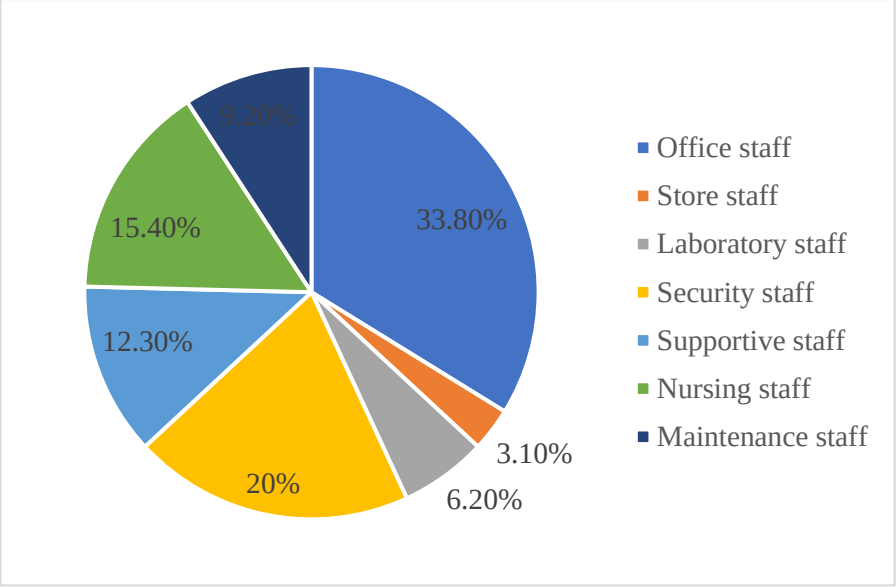

Figure 2 Staff position of the responders

Looking at the age distribution of the responders, a majority of them were between the ages of 20 and 49. 34.8% were in their twenties, 21.2% were in their thirties and 30.3% were in their forties. Only 9.1% of the responders were between the ages of 50 and 59 while the remaining responders (4.5%) were above 60 years of age.

When considering the number of years of employment of the responders, 21 had worked at the hospitals less than a year, while 18 had worked between 1 to 5 years. Another 13 responders had 6 to 10 years of employment at the hospitals and 12 had worked 11 to 20 years. The remaining 2 responders had worked for over 20 years at the hospitals.

5. Results of the Questionnaire

Nine of the responders have had experience with fires that had occurred in the hospitals. All the fires were minor and extinguished quickly, avoiding the spread of fire. The fires included electric fires in the kitchen and electric panel in Hospital A, a fire in the generator caused by lightning and an electric fire in the basement in Hospital B, and an accidental fire in a patient room in Hospital C.

When looking at the fire training provided for the hospital staff, over 70% responded that they had received basic fire management training and a little over 60% had some kind of knowledge regarding the usage of fire protection appliances such as fire extinguishers. The 13.6% of responders who replied to have partial knowledge in fire protection appliance usage denoted the staff members who had received theoretical knowledge in the subject but had not received practical training. Half of the responders had participated in fire safety drills. The statistics can be seen in Figure 3.

According to the staff personnel in charge of fire safety management in each of the hospitals, fire safety training programs, and fire drills for the staff are held at the hospital at least annually. In Hospital C, these programs are held around 8 times every year, so that all staff members experience the training at least once a year. The regularity of these programs can be credited to the requirement given by the fire service department in the country for privately owned hospitals to obtain a “Fire Safety License” annually to continue the operation of the hospitals.

It must be noted that in both Hospital A and Hospital B, the heads of the maintenance units of the hospitals were in charge of the fire safety management in the hospitals. However, Hospital C had a separate Fire Commander, whose main responsibility was fire safety management in the hospital.

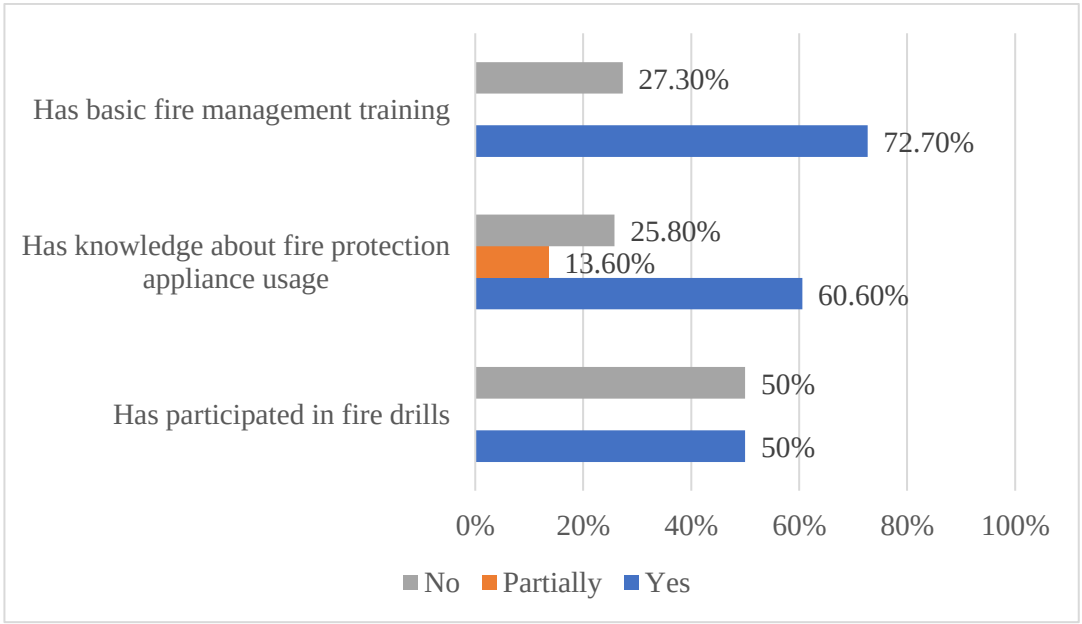

Figure 3 Fire safety training provided by the hospital to responders

When looking at the collected data, it was observed that the staff who had received most of the training were from the hospitals' maintenance units and security units. During the interviews, a majority of the responders (who were not maintenance of security staff members) relayed that if a fire were to occur, they would quickly inform the maintenance and security personnel about the incident.

Fire detection and alarm systems had been installed at Hospital B and Hospital C, but not in Hospital A. However, Hospital A had a manual emergency alarm system that was connected to the hospital reception and security office. Regarding sounding the alarm during a fire, a majority of the staff were aware of how to use the manual call points or emergency alarm. Only 3 out of 66 responders were not aware of the alarm systems. In areas where there were no alarm systems installed, the respondents have stated that they would use a mobile phone to send the alarm.

From the interviews, it was observed that the responsibilities during a fire hazard varied for each kind of staff. For office staff, there were no other responsibilities other than evacuation if the fire occurred at another place. In all three hospitals, the office areas were on the upper floors, so this course of action would be best for these staff members. If the fire were to occur in the office areas, the staff must operate the manual call point and try to extinguish the fire.

Considering the nursing staff of the hospitals, they are in charge of evacuating the patients of wards along with their medical files and other necessary materials safely to the designated assembly point or another safe place.

The major responsibility during a fire would fall to the maintenance staff and security staff. They would be in charge of directing the evacuation of the other staff as well as patients and hospital visitors. In Hospital C, there was a designated Emergency Response Team. They have been given advanced training in fire safety and consist of maintenance unit staff, security staff, and kitchen staff.

The staff personnel who will be in charge of notifying the local fire service department if necessary, according to the responders include maintenance staff, security staff, administrative staff, and reception staff.

Considering evacuation, staff members stated that an emergency evacuation without patients would take between 1 to 5 minutes, and evacuation with patients would take between 5 and 15 minutes. In reality, this would probably increase due to the traffic in stairways during an emergency.

When looking at the evacuation of patients, especially patients who will have mobility issues, more attention is needed. All staff personnel relevant for the evacuation activities of patients such as nursing staff, security staff, and maintenance staff in each of the hospitals were well aware of the standard procedures. During an emergency, if evacuation of patients who require assistance is necessary, the patients will be transferred to trolleys, stretchers or wheelchairs and evacuated along safe exit ways and exit staircases. The staff members were well aware of the necessity to avoid using elevators during an emergency. During the evacuation, the responders have stated that the evacuated patients must be accompanied by the patients' medical records as well as other relevant medical supplies necessary for the patients (e.g. oxygen cylinder, saline, etc.).

In Hospitals A and B, where assembly points had not been designated, most of the responders declared that assembly would be done in the open area in front of the hospital buildings or the roadway. This would both put the evacuees in danger as well as cause trouble for the fire brigades who would come in. The staff in Hospital C all had knowledge of the assembly point of the hospital as it has been clearly designated with a sign.

When asked to self-evaluate their preparedness to face a fire hazard in their workplace on a scale of 1 to 5, with 5 being extremely prepared, the responders replied as can be seen in Figure 4. Over 68% of the responders have evaluated themselves as at least 75% prepared to successfully face a fire.

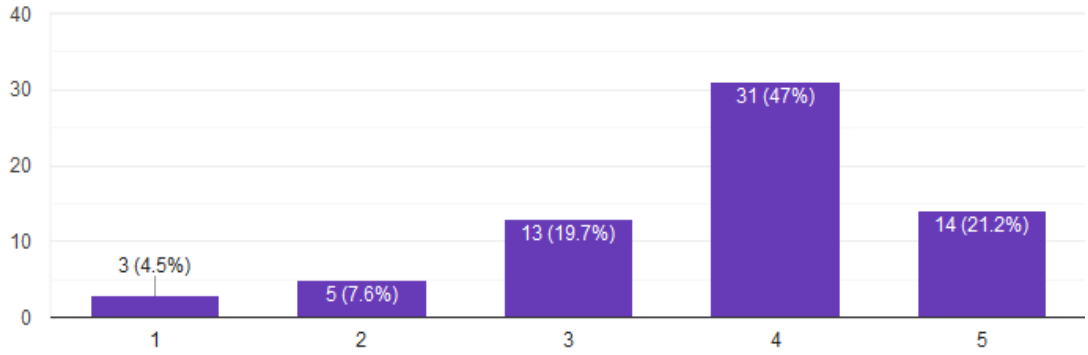

Figure 4 Self-evaluation of the responders regarding their preparedness to face a fire hazard

6. Conclusions and Recommendations

6.1 Conclusions

Carrying out fire prevention practices is the best way to manage the risk of fires. However, there is always the possibility that a fire hazard could occur despite the strictest measures taken to minimize the risks. Therefore, a hospital and its management should always be prepared for fire protection as well. This preparedness should include the preparedness of all staff members to face a fire hazard.

From the survey, it has been identified that a majority of staff members in privately owned hospitals are at a high preparedness level in terms of fire with over 60% having training in the use of fire protection equipment and over 70% having received basic fire management training. This is in contrast to government-owned hospitals, as a recent study in two major tertiary hospitals observed a distinct lack of training in fire management for staff members [12]. The survey found that the duties and responsibilities of staff members in Hospitals A, B, and C in the event of a fire hazard had been identified. The major responsibilities in such an event were given to the staff of the maintenance and security units of the hospitals. These responsibilities include extinguishing the fire, evacuating people in the vicinity of the fire, and notifying the local fire service department. The main responsibility of evacuating patients falls to the nursing staff and supportive medical staff in the respective hospital wards.

Annual fire hazard management training and drills are conducted by each of the three hospitals, as this is a partial requirement in obtaining the annual “Fire Safety License” which is required for the continued operation of a privately owned hospital. The same requirement is not present for government-owned hospitals.

6.2 Recommendations

It is important that a hospital has a fire safety plan, which should include a fire action plan. The fire action plan should include the procedures for initial fire suppression, fire evacuation, and corresponding with the local fire service department. The fire action plan must state the

specific responsibilities of staff members in the hospital. It is advised that a hospital has a separate fire safety officer, who will oversee and control the fire safety practices in the hospitals.

When considering fire safety training and fire drills, it is recommended that all staff are required to undergo the programs. However, if this cannot be done, the training should be provided in such a way that at least a few staff members from each department are included. It is important that fire safety training is provided at least annually to the hospital staff. Realistically, it is not possible to hold a program for all the staff members at the same time, considering the staff size in a major hospital, shift-based duty of hospital staff as well as the regular duties of the staff which are needed at all times of the day. Therefore, it is recommended that fire safety training is provided for groups of the staff to gain an optimum level of staff preparedness.

When delegating staff responsibilities for a potential fire hazard, the responsibilities should coordinate with the regular responsibilities of each staff member. For example, taking care of patients and evacuating them safely if necessary, should be done by nursing staff and other medical staff. Fire suppression and directing evacuation should be under the responsibility of the hospital's security staff and the maintenance staff. Contacting the local fire service department should be done by the fire safety officer or the administrative staff.

In a hospital, the evacuation procedures for patients must be taken seriously. Often times during a fire, lives could be saved by remaining in place rather than rushing to evacuate through a smoke dense path. Therefore, the fire safety officer should develop proper emergency evacuation paths and procedures. Also, coordination between staff in different areas of the hospital is important during a fire hazard.

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