POST FIRE REFURBISHMENT OF APPAREL MANUFACTURING BUILDINGS FOR ENHANCED BUILDING PERFORMANCE

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ABSTRACT

Post Fire Refurbishment of Apparel Manufacturing Buildings for Enhanced Building Performance

The essence of buildings in apparel sector is highly influenced on the efficiency and effectiveness of occupants' performance and comfort. Creation of user satisfaction can be reached through the involvement of building performance mandates (BPMs) within the interplay of total building performance (TBP). TBP is affected by numerous reasons. Among those, fire incidents may cause direct or indirect impacts to the present building or even in old age. Consequences of these fire incidents in apparel buildings lead to building refurbishments which intended to reinstate the building condition as well as to improve the quality of life. Nevertheless, evaluation of post-fire refurbishment projects mainly focused on building integrity in terms of mechanical and physical properties. However, there are no evidence of any building evaluation especially focusing to the other performance mandates in post fire building refurbishment. Therefore, equal importance should be given to other five BPMs (spatial performance [SP], thermal, acoustic [TP], indoor air quality performance [IAQP], visual performance [VP] and acoustic performance [AP]) in order to achieve building functionality and comfort of the building occupants.

The study was conducted by involving the concurrent nested mixed design under mixed research approach. An extensive literature review and case studies of three fire affected apparel buildings were involved as data collection methods. Literature review was conducted in order to review the behaviour of building fires, factors contribute to building fire incidents, hardware and software measures of fire safety and models for building fire impact evaluation. Moreover, refurbishment of fire damaged buildings and its impact on building performance were recognised through the literature review. Data collection were supported by eighteen semi structured interviews and a questionnaire survey among thirty-six respondents. Collected qualitative data analysed using manual content analysis and quantitative data analysed by relative importance index (RII).

The results revealed that due to the business nature of apparel sector holds high risk for fire incidents. To fight against high fire risk in apparel sector, better symbiosis between elements of fire detection, notification and suppression emphasised by the current research. On the other hand, lack of practice on passive fire protection and unavailability of apparel sector specific fire regulation in Sri Lanka asserted as a practice which hinder the effective building protection against fire. To safeguard the building from critical fire incidents, forty-nine factors highlighted and strategies to overcome the identified loopholes elaborated in the current study. Accordingly, 'faulty wiring' was ranked with highest relevance followed by 'welding work with electrical sparks'. Importance of BPMs for apparel manufacturing buildings was analysed to enhance building performance in post-fire situation. Then existing best practices of BPMs in the apparel sector were discussed. Even though these BPMs essential to apparel manufacturing sector, the better application of BPMs have been limited by many challenges in the business operation. The research identified forty-five (45) challenges encountered in maintaining BPMs of post fire refurbished apparel manufacturing buildings and provided strategies to overcome the identified challenges. Finally, a framework was developed by incorporating main three themes, push factors and pull factors identified in the study to enhance the performance of post-fire apparel buildings beyond restoration.

Keywords: Building Performance, Fire, Apparel Buildings, Refurbishment

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EQUATIONS

ABBREVIATION

AP	Acoustic Performance
ASHRAE	American Society of Heating Refrigerating and Air Conditioning Engineers
BAW	Berkeley Architectural Walkthrough
BOI	Board of Investment's
BPMs	Building Performance Mandates
CIDA	Construction Industry Development Authority
CMFST	Consolidated Model of Fire and Smoke Transport
FDS	Fire Dynamics Simulator
FPEs	Fire Protection Engineers
FSCT	Fire Safety Concept Tree
FSES	Fire Safety Evaluation System
FBFSEM	Fitzgerald's Building Fire Safety Evaluation Model
FD	Fluctuation of thermal discomfort
GFR	Generic Fire Response
IAQ	indoor air quality
IAQP	Indoor Air Quality Performance
ICI	Integrated Characteristic Interaction
ITD	Intensity of thermal discomfort
NFPA	National Fire Protection Association
RII	Relative Importance Index
SP	Spatial Performance
TP	Thermal Performance
TBP	Total Building Performance
UDA	Urban Development Authority
VP	Visual Performance

CHAPTER 1

1.0 INTRODUCTION

1.1 Background

Buildings are long-lasting infrastructures which usually designed to withstand over 60 years (Le, Park, Domingo, Rasheed, & Mithraratne, 2018). Durability or performance of the building are affected due to numerous reasons and among that fire incidents may cause direct or indirect impacts to the present building structure or even in old age (Shokouhi et al., 2019). Fire incidents have considerably increased during last years by endangering human lives and causing economic and ecological damages (Félix et al., 2014). At local to regional scales and at global scale, emissions due to fire incidents have significant impact on air quality and atmosphere (Preiser et al., 2017). Not only that, after a fire people tend to be traumatized due to the losses of belongings. Among that, losing the building is one of the most stressful factors for a building owner (Caia et al., 2010).

Even there are plenty of active and passive fire safety measures available, fire resistant building is still a major challenge worldwide (Chow, 2005). According to World Fire Statistics Report 2018 No. 23, which reported in years 1993-2016, 2.5 to 4.5 million fires occurred and nearly 62, 000 fire deaths were reported from 57 countries (International Association of Fire and Rescue Services, 2018). Among these countries, highest fire rates relative to population are found in Australia, Bulgaria and Israel. United States of America as a developed country reported 1 342 000 fires and 3 390 fire deaths in year 2016 (International Association of Fire and Rescue Services, 2018). India Risk Survey 2017 report has stated a total of 18, 450 fires with 1, 193 injuries and 17, 700 deaths in year 2015 (Jha, 2017). Accordingly, not only in developed countries, same risk can be seen in developing countries too.

Asian region is identified as the second highest region with fire safety non-compliance and fire incidents have identified as the second highest disaster topology in Sri Lanka (Sedex Information Exchange, 2013; Disaster Management Centre, United Nations Development Programme in Sri Lanka, & United Nations Development Programme Regional Centre, Bangkok, 2009). Sri Lanka National Report on Disaster Risk,

Poverty and Human Development Relationship-2009 has reported 2703 major fires between year 1974 and 2007 (Disaster Management Centre, United Nations Development Programme in Sri Lanka, & United Nations Development Programme Regional Centre, Bangkok, 2009). Fire erupted at Kotahena girls' hostel due to technical failure, three-storey clothing shop in Wattala, Aluthgama market, one-hundred and twenty-two shops in Pettah and a factory and three houses in Kotahena can be shown as examples for fire recent incidents in Sri Lanka (News1st, 2019).

Considering fire issues in different industries, highest number of non-conformities were reported in manufacturing sector among all the other sectors in each region (Sedex Information Exchange, 2013). Rubber processing factory in Mattegoda, plastic bottles manufacturing factory in Mawinthara, Piliyandala and factory in Galgamuwa, Sri Lanka have completely burnt down due to fire incidents (News1st, 2019). Further, fire incidents occurred in automotive manufacturing factory in China (damage:146 fatalities and 114 injured workers), the Tazreen fashion factory in Bangladesh (damage: 111 fatalities), textile factory in Pakistan (damage: more than 300 fatalities) firework factory in Denmark (damage: several fatalities and injuries, 8 fires and a rescue vehicle destroyed, 355 houses damaged and over 2000 buildings damaged) and the Kader Toy factory in Thailand (damage: 188 people were killed, over 500 were seriously injured and fine of $ 15,700) were reported as world's deadliest manufacturing fires (McClure, 2018).

Moreover, when considering about different sectors in manufacturing sector, apparel manufacturing sector represent a significant role by contributing in the national economy of many countries (Li, Xu, & Li, 2016). According to Lanier Pence et al. (2003) apparel manufacturing sector deals with highly flammable materials and situations (combustible dust, hot work equipment, flammable fabric, liquid and gasses, and electrical hazards) and also large number of employees work in apparel manufacturing buildings. Accordingly, Wadud and Huda (2016) highlighted the number of fatal accidents and damages in apparel manufacturing sector which shows the significant impact of fire in this sector. Hence apparel manufacturing sector represents the highest portion of fire incidents in different industries worldwide. In 2012, nearly 112 workers were killed by a fire at Bangladesh's Tazreen Fashions

factory due to the building's short circuit on the ground floor (Prentice & Neve, 2017). Thereafter, the fire quickly spread through to the nine floors, where factory workers were trapped because of narrow or blocked fire paths and many of them died inside the factory. Moreover in 2013, fire broke out at the Tung Hai Sweater Factory in the Mirpur district of Dhaka and 8 people were died (East Asia Pacific, 2013). East Asia Pacific (2016) discovered that a fire that erupted the garment factory in New Delhi, India caused to kill at least 13 workers. Also, there was a fire occurred in the garment factory in Karachi, Pakistan and 289 people were died due to unavailability of fire exits to evacuate from the building (Shoaib, 2012).

Apparel manufacturing sector in Sri Lanka plays a noteworthy role by contributing 40% of total exports and around 50% of industrial exports in Sri Lanka. Due to the favourable developments in GSP + scheme, the apparel sector donated nearly 80% of total growth in the manufacturing sector in year 2018 (Central Bank of Sri Lanka, 2018). Even though, the apparel manufacturing sector contribute to country's economy, frequent fire incidents affect to the better performance of apparel buildings in grate extend (Sustainable Report, 2017). Several fire incidents can be identified from the Sri Lankan apparel manufacturing industry too from the past decades. One of the famous apparel factories in the Board of Investment's (BOI) export processing zone in Katunayake affected by severe fire incident (Sustainabilty Report, 2017). Apart from that, several fire incidents were reported from medium-scale apparel manufacturing organisations too. Fire incidents at a factory in Sadalankawa, Pannala, warehouse of a garment factory in Wattala and a garment factory in the Ratmalana area can be identified as noticed fire incidents through news reporting (MTV Channel Private Ltd, 2015 & 2019).

Refurbishment activities need to be performed in fire damaged buildings in order to gain economic and social enhancement, as well as the total life span of the building can be significantly extended by effective refurbishment (Hashim, Aksah, & Said, 2012). Refurbishment perform to reinstate the buildings to match the previous operational status. Refurbishment means to keep the original design features while bring it up to standard or to turn it to the new use (Hashim et al., 2012). The aim of the refurbishment is to provide improvement or modification of existing building in order

to meet acceptable conditions (British Standard 15643-1, 2010). Instead of demolition, partial refurbishment or full refurbishment is a better way to recover the building at the end of its service life (Shah Ali et al., 2009). According to Egbu, Young and Torrance (2002) refurbishment is in several forms, such as adaptation, alteration, extension, improvement, rehabilitation, modernization and repairs which is to gain existing building to re-use. The need for refurbishment projects can be divided into types such as change in use, corrective refurbishment, optimizing refurbishment, space alteration refurbishment, and change of environment and subjective features as pleasure refurbishment (Hashim et al., 2012). Impact of the fire event directly influence to the condition of the building and direct to refurbish building or to reconstruct the capacity of building (Félix et al., 2014). In general practice, refurbishment conduct by focusing on physical structure of the building while ignoring Building Performance Mandates (BPMs) (Sui Pheng et al., 2012).

Accordingly, such shocking fire events directly challenge the essence of the apparel manufacturing buildings especially in terms of building performance. Facilitating comfort to the occupants is one of the key purposes of any building (Celik, 2010). According to Celik (2010) play an important role in facilitating comfort to the building occupants. BPMs comprise of six aspects: spatial performance (SP), thermal performance (TP), indoor air quality performance (IAQP), visual performance (VP), acoustic performance (AP) and building integrity (Oyedele et al., 2012). Félix et al. (2014) have explained that building fire critically affect to the functionality of these performance mandates. Over the years, Total Building Performance (TBP) has been a vital concept among many researchers and industry practitioners (Wong & Jan, 2003). TBP is measured and evaluated by the above mentioned six BPMs (Sui Pheng at al., 2012). Further, Sui Pheng et al. (2012) identified that BPMs provides comfortable environment for building occupants and support for their well-being.

According to Sui Pheng et al. (2012) spatial arrangement is an essential component for every building and should consider, the work performed, furniture and machine used, storage requirement and number of occupants (Wong & Jan, 2003). TP mandates refer to three components; temperature, relative humidity and air movement (Sui Pheng et al., 2012). Acceptable limits of thermal performance differ from place to place. As

stated by Wong and Jan (2003) general non –conditioned area has temperature (24–28°C), relative humidity (20-70%) and average air movement (< 0.8 m/s). Further, severe microbial and indoor air quality (IAQ) problems can occur due to high relative humidity (Sui Pheng et al., 2012). Occupants feel discomfort and lose their attention when air movements are beyond the standard range. According to Wong and Jan (2003) during or after a fire event, small movements of building caused as a result of the thermal displacements. IAQP directly influence the core function of any type of building (Nazaroff, 2013). In past years, questions regarding air tightness of working environment was raised as a focus of air quality and occupant health (Nazaroff, 2013). Further, Nazaroff (2013) explained that efficiency of ventilation is measured by the level of carbon dioxide prevailing in the building space. According to Hui, Wong and Mui (2007), acceptable concentration of carbon dioxide is between 800-1000 ppm for indoor space. Carbon dioxide concentration beyond the acceptable level may cause physiological effect, such as sensation of breathing difficulty, fatigue drowsiness and lack of concentration (Nazaroff, 2013). Moreover, allergic asthma can be recognized as one of the common health complaint regarding IAQ and suspended particular matter can be identified as the core reason for asthma (Kinnear, 1986).

Illuminance measurements which are used to evaluate VP and different illuminance levels can be recognised for different tasks and different functional areas of the building (Sui Pheng et al., 2012). Glare can be identified as a common problem in VP. Poor AP leads to stress, annoyance, communication problems and poor conversational habit (Wong and Jan, 2003). Building's AP is impacted by noise from vehicles and noise from other buildings other than the internal noise. Building integrity consider three properties such as structural or mechanical properties (tension, compression), chemical or physical properties (air-tightness, water-tightness, fire safety, absorption of light, sound and heat), and visible properties such as finish, colour, texture, maintainability and durability (Kinnear, 1986).

Accordingly, vital importance is given to fire safety of a building structure in order to safeguard the total performance of the building (Wong & Jan, 2003). Henceforward, the refurbishment of fire damaged building is in the centre of interest nowadays

(Maraveas et al., 2017). Hence this research was focused on building performance of post fire refurbished buildings of manufacturing industry in Sri Lanka.

1.2 Problem Statement

Significant improvements in individual performance and in overall business growth can be accomplished through a sophisticated interplay of BPMs (Sui Pheng et al., 2012). Nevertheless, main focus is given to economic advancement in the business while ignoring the quality of life within the building (Hong et al., 2017). Further to authors, poor attention on BPMs will result in long-term productivity issues and occupant discomfort. An occupant satisfaction survey in United States repeatedly have reported that they are dissatisfied with their working environment in relation to visual, air quality, thermal, acoustic and spatial-ergonomics aspects (Hong et al., 2017). A study conducted in education building, United Arab Emirates have identified eyestrains, muscular pains, irritability, blurring vision, drowsiness and headaches due to poor visual performance of the building (Ada et al., 2019). According to Bayer (2001), serious microbial and indoor air quality issues arise when the relative humidity is high in thermal performance of the building. Further, authors identified occupants cannot pay full attention as a severe problem due to thermal discomfort of the working environment (Bayer, 2001). Development of poor conversational habits, communication problems and annoyance can be occurred with the poor acoustics environment and momentous physiological effects namely; lack of concentration, fatigue drowsiness and sensation of breathing difficulties are reported in poor indoor air quality (Wong & Jan, 2003).

Not only in developed countries' scenarios, but also developing countries such as Sri Lanka face the same BPMs related issues (Nandasena et al., 2010). Nandasena et al. (2010), have reported that the indoor air is extremely contaminated than outdoor air in Sri Lanka. Wijerathne (2011) has identified that apparel workers in Sri Lanka frequently affected by poor air quality. Halwatura and Jayasinghe (2008) have identified that most of the tropical countries including Sri Lanka suffering with thermal discomfort and high energy demand also prevailing with that. According to the current crisis in urban environment in Sri Lanka, sufficient space requirement is rarely fulfilling by many apparel buildings. Due to this situation, spatial comfort within the

building is an obvious query (Panditharathene, 2000). Accordingly, total performance of the building is not adequately review by building owners even though it is major requirement to enhance the business productivity.

This situation gets sever when the building is affected by fire (Wong & Jan, 2003). According to Wong and Jan (2003) during or after a fire event, TP of the building dramatically changes unexpectedly. Especially fire damaged building is displayed as in black colour due to extensive smoke damage and it leads to visual discomfort and poor IAQ (Wong & Jan, 2003). Moreover, visibility also can be absent due to the damage of artificial lighting system of the building (Kinnear, 1986). Generally, soon after the fire, building condition assessment will be performed and these evaluations are mainly focused on the building integrity (Annerel & Taerwe, 2011). Sufficient literature can be found for evaluating post fire - building integrity performance in terms of mechanical properties and physical properties. Lau et al. (2016) have examined structural strength, durability and weather-tightness of post-fire concreate building. Further, Clifton and Feeney (2004) inspected the building stability of multi-storied steel structure after a fire incident. However, there are no evidence of any building condition assessment specially focusing to the other performance mandates in post fire building refurbishment. Therefore, equal importance should be given to other five performance mandates (SP, TP, IAQP, VP and AP) in order to achieve building functionality and comfort of the building occupants.

As a step towards the sustainable development of Sri Lanka, apparel manufacturing sector represent a significant role with the second highest contribution to total export in Sri Lankan economy (Trade Economics, 2019). On the other hand, Apparel manufacturing sector is frequently reported with many fire incidents per year which disrupt the best utilization of occupants and the process of manufacturing sector in Sri Lanka (Department of Community Medicine, 2016). As a timely requirement with the previous severe fire incidents and the identified literature gap which was mentioned above, there is a noteworthy necessity of examining the building performance of post-fire refurbished buildings of Sri Lankan apparel manufacturing sector.

1.3 Aim and Objectives

Aim

The aim of this study is to examine building performance of post-fire refurbished buildings in apparel manufacturing sector in Sri Lanka.

In order to review this aim, following objectives have been formulated.

Objectives

1. Study the extent of building fire risk and factors contribute to fire risk in apparel manufacturing sector
2. Explore the importance of BPMs for refurbishment of fire affected buildings in apparel manufacturing sector
3. Investigate the challenges of managing BPMs and strategies to restore the performance of fire damaged buildings in apparel manufacturing sector
4. Develop a framework to enhance the performance of the post fire apparel buildings beyond restoration

1.4 Research Methodology

This study adopted a concurrent nested mixed research approach to pursue the aim of this research, which is to evaluate building performance of post-fire refurbished buildings of manufacturing sector in Sri Lanka. Initially, a background study was directed to identify the gap in the research and formulate the research problem, aim and objectives. Subsequently, an extensive literature review was conducted to understand the extent of building fire risk in apparel manufacturing sector. To conduct literature review; journals, conference proceeding, government publications, reports, newspapers and websites will be used as sources.

Further, to fulfil other objectives multiple holistic case study approach was conducted as research strategy, since the aim of this research mandated in depth investigation (Kale & Kale, 2009). Data collection was facilitated through three (03) fire damaged apparel manufacturing buildings. As data collection tools; expert interviews with eighteen professionals and a questionnaire survey were conducted. The collected data

were analysed through quantitative and qualitative analysis techniques. Finally, a framework was established to enhance the building performance beyond restoration.

1.5 Scope and Limitations

The scope of this study was outlined to evaluate building performance of post fire refurbished buildings of apparel manufacturing sector in Sri Lanka. Research considers the BPMs, including SP, TP, IAQP, VP and AP. Moreover, this research was limited to apparel manufacturing sector based on the fire risk, statistics and data saturation. Furthermore, data collection was conducted in Western province and North Western province with the intension of conducting a comprehensive study within the time bound.

1.6 Chapter Breakdown

The research was structured based on five chapters as discussed below:

Chapter 1 – Introduction

The chapter 1 presents the introduction to the research with a background study, aim, objectives, methodology and scope and limitations of the research. The research aim was formulated to evaluate building performance of post-fire refurbished buildings of apparel manufacturing sector in Sri Lanka.

Chapter 2 – Literature Review

Chapter 2 presents a literature synthesis focusing on the building fire incidents, BPMs and significance of refurbishment projects to enhance the building performance of fire damaged manufacturing buildings.

Chapter 3 - Research methodology

Chapter 3 presents the research process, research approach, research strategy, data collection and data analysis techniques. This research was adopted a concurrent nested mixed approach and focused on case studies of three (03) apparel manufacturing buildings in Sri Lanka.

Chapter 4 –Data Collection, Analysis, Research Findings and Discussion

Chapter 4 presents the findings of the three (03) refurbished apparel manufacturing buildings. Data were mainly gather using interviews and a questionnaire survey. Collected data analysed using manual content analysis and RII technique.

Chapter 5 – Conclusions and Recommendations

Chapter 5 presents the overview and the conclusions of the study and describes the contribution of this research to body of knowledge. This chapter was further discussed about the limitations of this study and prospect further research.

1.7 Chapter Summary

The aim of this study is to evaluate building performance of post-fire refurbished buildings of apparel manufacturing sector in Sri Lanka. Four objectives are lined up to achieve the aim of the research. A comprehensive background for the research problem was developed through literature review. Mixed approach was involved as the research approach. Findings of qualitative data were evaluated using manual content analysis. Relative importance index (RII) technique used to analyse quantitative findings.

CHAPTER 02

2.0 LITERATURE REVIEW

2.1 Introduction

Chapter one depicted an outline to the research topic and the research problem. Chapter two intends to strengthen research using comprehensive literature synthesis. The chapter brings forward literature findings under main three phenomenon, namely; building fire incidents, refurbishment of fire damaged buildings and its effect of BPMs.

2.2 Building Fire

Buildings are long-lasting infrastructures which usually designed to withstand over 60 years. Generally, majority of people work and live in buildings and buildings are contributed for environmental, economic, functional, cultural and legal significances (Douglas, 1996). Durability or performance of the building is affected by numerous reasons and among that fire incidents may cause direct or indirect impacts to the present building or even in old age. Architects and other designing party make various design decisions which consider functional and aesthetic features in order to fulfil requirements of clients and other stakeholders as well as to comply with building codes and standards (Lidwell, Holden & Butler, 2010; Reichard & Papamichael, 2005). Among that, fire safety is a vital requirement, although it gains low priority (Park, 2014). Fire incidents have considerably increased during last years by endangering human lives and have caused economic and ecological damages (Félix et al., 2014). Further, fire is one of the most common accidents, which damage can be limited or wide range (Chow 2005). Common reasons for this negligence is that the fire safety features of a building do not provide any clear benefits namely, aesthetic pleasure, cosiness, or convenience and they are only beneficial for a fire situation, which is unlikely to happen (Park, 2014). Unexpected operational issues and design errors are some of the common reasons for fire events. High occupancy density, complex building environment and combustibles contribute to fire that can result in disastrous casualties. Even there are plenty of active and passive fire safety measures available, fire resistant building is still a major challenge worldwide (Chow 2005).

Every building structure has a fire risk, and it is believed that complete safety from fire is almost an impossible task (Abraham & Stollard, 2002). There are vast number of fire events happened worldwide but they are highlighted and attracted public attention only when fire caused serious damages or fatalities (Abraham & Stollard, 2002). World Fire Statistics Report 2018 No. 23, which reported fire incidents in year 1993-2016, 2.5 to 4.5 million fires occurred and nearly 62 000 fire deaths were reported from 57 countries (International Association of Fire and Rescue Services, 2018). According to World Fire Statistics Report 2018 No. 23, highest fire rates relative to population are found in Australia, Bulgaria and Israel (International Association of Fire and Rescue Services, 2018). United States of America as a developed country reported 1 342 000 fires and 3 390 fire deaths in year 2016 (International Association of Fire and Rescue Services, 2018). India Risk Survey 2017 report has stated a total of 18, 450 fires with 1, 193 injuries and 17, 700 deaths happened in India in 2015 (Jha, 2017). Considering past fire incidents in different building perspective, worthwhile findings can be revealed. Most of the fatal fires happen at night in residential buildings, hotels, hospitals and hostels where people are sleeping, in buildings occupied by disable people, and in assembly buildings which have high density occupancy. Disastrous result of fire happen when it occur in crowded buildings (Li & Zlatanova, 2007). These life threatening situations leading to fatalities as people are crushed or trampled.

The Cocoanut Grove Dance Hall Fire in 1942 can be identified as one of the shocking fire incident happened in the history (Kobes, 2010). The fire was resulted 490 deaths. A video of Station Nightclub fire discovered that within ninety seconds of start, fire turned into massive fire and whole environment of night club became indefensible, and resulted 100 deaths and 200 injured people (Grosshandler et al., 2005; Bryner et al., 2007). The fire at the Station Nightclub in 2003 is considered as the fourth deadliest fire in United States history (Aguirre et al., 2011). A fire in a coffee machine was caused to the fire in Delft University of Technology in Netherland (Gane & Haymaker 2010). The fire was started around 9 AM in the 6^{th} floor and rapidly spread vertically to the eleventh floor of the south tower in year 2003. Then fire spread to the north tower and around eight hours after the fire started the north tower collapsed partially.

Further, famous fire incidents in King's Cross underground station in 1987, where 31 people died and Bradford City football ground in 1985, where 56 people died (Cheng et al. 2001). Summerland indoor multi-storey leisure complex in Douglas which was the largest and most innovative indoor entertainment centre in the world. The complex was built with wall and roof of transparent acrylic sheeting. Small fire started due to discarded smoking materials in a fire glass kiosk. Later, kiosk collapsed into the building and spread fire rapidly along flammable walls and roof of the complex, resulting warped, melted and then collapsed the structure (EffectiveSOFTWARE, 2017). Another massive fire occurred at a high-rise building in Hong Kong in year 1996 (Wong & Lau, 2007). Due to the ongoing construction, all the lift doors had been detached and this vertical windows and other openings allow rapid spread of flames throughout the building (Wong & Lau, 2007). According to John (2017), the Grenfell Tower in London turned into a torch in 2017 which has recognised as the deadliest structural fire in the United Kingdom. The fire was started by a faulty refrigerator on the 4th floor and rapidly spread to building exteriors which resulted 72 deaths, 151 houses destroyed and more than 70 injured people. Apart from that, in year 1666, a severe fire event happened in London and another famous fire event occurred in Hamburg which are caused to significant damages to Hamburg residents in 1891 (Halliday & Booth, 2019). These fire disasters occurred in developed regions where advanced technologies and strict fire safety standards are applied. If such catastrophic fires could go off in developed countries, unnecessary to mention that it is significantly important to review fire safety in developing countries (Hajibabai et al., 2006).

2.3 Behaviour of Building Fire

Actual situations of fire incidents can be evaluated through the proper understanding of the behaviour of building fires. Civilisation might not even exist or would be radically different without presence of the fire (Abraham & Stollard, 2002). Fire is one of the most common accidents which damage can be limited or wide range (Chow, 2005). Fire can be beneficial but it can also be deadly. Basically, fire reacts with oxygen and release heat and particular substance is destroyed. In the general fires, when temperature is low, colour of flame displays from red to yellow, white fire flame can be seen in a high temperature (Arrue, 2000). This discovers that high-saturation

light emits in low temperature and low-saturation light emits in high temperature. Changeable shape of the fire can be recognized due to airflow caused by wind and smokes of the fires vary with the combustible material (Arrue, 2000). Factors that may cause for fires should be identified to have a better fire safety system (Chow, 2005). In detail, three main elements should be present in order to ignite a fire which is known as fire triangle; namely: oxygen, fuel and heat. The combustion phenomenon of fire is defined as rapid oxidation accompanied by light and heat. Chemical combination of any substances with oxygen can be recognised as oxidation (Hasofer et al. 2011). The classic triangle concept of fire is identified oxygen in some form, fuel (material) and heat to maintain combustion as three key factors for a fire (Hasofer et al. 2011). Further, the concept is explained that removing one factor will extinguish a fire by opening the triangle and to prevent a fire from starting, any one factor should be keep from joining the other two factors. Later, classic triangle concept was challenged by a recent research, which introduced a fourth factor (Hasofer et al. 2011). The study explains that combustion process is not as simple as the classic triangle, there is a fourth factor; chemical chain reaction which acts as a reaction chain to accelerate the burning. Hasofer et al. (2011) formulated tetrahedron theory which discuss the diffusion flame combustion fire phenomenon. Author symbolised the concept as a tetrahedron instead of a square since the four factors are adjoining and each factor is connecting with other three factors.

Chang and Huang (2005) have discussed about rate of fire growth based on the exponential growth, which explain effect of fire growth coefficient of burning material. Accordingly, Bailey et al. (1996) have found that fires spread both horizontally and vertically within the building. Common reasons for horizontal fire spread are open of fire doors, breakdown of compartment walls, extinction, ventilation conditions and to balance of fuel supply (Bailey et al. 1996). Vertical spread of fires can be due to flames being directed through broken windows, through a lobby or vertical shafts. Further, Chang and Huang (2005) have discovered nine fire curves according to different fire growth rates. Fire growth involving synthetic materials such as polyurethane is known as ultra-fast fire growth. Accordingly, researchers have

declared that the rate of fire growth is a vital consideration in defining fire effects (Kobes et al. 2010; Sime 2001).

2.4 Factors Contribute to Building Fire Incidents

Failure to consider the causes for building fire incidents leads to under-performance of existing fire safety system in buildings (Xiuyu et al. 2012). This implies that there is a necessity of reviewing factors affecting the building fire incidents. Average five or six people die in fires each day in the United Kingdom and this case is more similar to many countries around the world, therefore to identify various factors that are result in massive fires is a major requirement since cost of fires are in uncontrollable level.

2.4.1 Building Design Features

Various design features and their integration into the fire safety system can be recognised as one of the main reasons for poor fire safety in buildings (Park et al. 2014). Dominant influence for fire can be seen from openings in the compartment by supporting to combustion with air supply. Further, researchers insisted that the flow of air is directly impacted on burning rate of the fire (Chow & Zou 2005; Utiskul 2005). Fires occurred in Delft University, King's Cross station, Bradford City building and the Crowne Plaza Hotel can be recognised as critical fires happened due to poor design features.

Fire incident in the Delft University of Technology in Netherland was an example for massive fires due to design features (Lottman et al 2013). The building was consisted with horizontally continuous window which installed throughout the structure and a mezzanine floor which were allowed openness and closeness. The Faculty of Architecture building was made of concrete and steel and also with tremendous fire resistant materials. Structure had fulfilled building codes in the Netherland. However, neither vertical fire suppression nor horizontal fire suppression was achieved (Park et al. 2014). Fire investigation revealed that there were various building structures which donated to the speed fire development and supported to a vertical fire spread (Park et al. 2014). Moreover, the tall exterior window was encouraged large flames and horizontally continuous window acted as a channel for horizontal fire spread. In detailed, fire spread was due to open of fire doors, breakdown of compartment walls,

extinction and ventilation conditions can be identify as reasons for horizontal fire spread in the University building (Lottman et al 2013). Besides, vertical spread of fire was due to flames being directed through broken windows, through a lobby or vertical shafts (Lottman et al 2013).

Old and wooded building structure were recognised as causes for fire incidents in King's Cross station and Bradford City building (Cheng et al. 2001). Fire incident at the Denmark Crowne Plaza Hotel reported that firefighters took nearly 8 minutes to just find the door to reach the fireman's elevator which is placed within less than a 30 meter radius (Moriarty 2019). Later, investigators were identified that the reasons for took this much of time to find a door is due to absent of proper naming on the fireman's elevator and had the same colour for door and its background walls which make difficult to identify the door (Moriarty 2019). This design was considered as effective from architects' viewpoint because it provides an intellect of a hidden space which actually planned to be used only for staff of the hotel. However, due to this design error critical delay happened in rescue process.

2.4.2. Refurbishment Practices

Fire safety must be considered not only in building design, construction and operation, but also in the refurbishment process. A high-rise building in Hong Kong was caught for fire due to improper refurbishment practices (Wong and Lau 2007). Lift shaft which was undergoing refurbishment was analysed as the reason for the quick fire spread in the building. During the process of refurbishment of lift shaft, all its doors were removed. And also, temporary plywood panels were involved even though they were not well sealed. These vertical openings allow rapid development of flames throughout the building (Wong and Lau 2007).

2.4.3 Human Behaviour

Human behaviour can be recognised as messy and unpredictable actions which considered as the core of fire safety (Kuligowski, 2016). The Hong Kong fire incident in high-rise building further discovered that the bottom of the lift shaft was accumulated with garbage, hence supporting a massive fire danger (Wong and Lau 2007). Welding work which had electric sparks was reported as ignition source with

highly flammable materials. Not involving the building for its' original design function was identified as a cause for a fire incident in Hong Kong. The high-rise building was constructed for commercial and residential purpose, but later the building was used for industrial practices. Lack of quick response of fire brigade has identified as a reason for recent fire event happened in Kandy, Sri Lanka (Daily News, 2019). Further, Wong and Lau (2007) have explained that many construction workers are flipped away their cigarette while there are working in the refurbishment project. Careless smoking in the refurbishment, sloppy maintenance on electrical tools, faulty wiring, and lack of adequate fire watch can be identified as common human errors. Not only that, many multi-story building can be seen with lot of debris and waste items around the building. Further, careless or disgruntled workers and uneducated occupants can create fire hazards.

2.4.4 Fire Regulation, Policies and Building Codes

Designs for fire safety and protection in building are determined by building regulations. Legislation tries to assign minimum standards of safety which building stakeholders must comply (Li and Zlatanova 2007). Most of the building design does influence fire safety while others not. These building fire safety codes and standards are in acted to avoid any unexpected losses in the building. But, building owners and responsible parties are tending to fulfil only the least fire safety requirements in the codes or standards (Li and Zlatanova 2007). On the other hand, some buildings are over maintained by fire safety provisions which are not cost-effective. Architects are reported that traditional building codes are not integrated with fire scenarios (Li and Zlatanova 2007). Furthermore, architects are complained that they cannot easily incorporate novel building concepts due to restrictive building codes. Therefore, they tend to follow basic requirements, such as exit with and travel distance (Li and Zlatanova 2007). Further, Di Bella, A., Fausti, P., Scamoni, F., & Secchi, S. (2012) has discovered that the technical standard UNI 11367 is still not a mandatory and it acts as voluntary requirement because the need of significant amount of time and other resources for proper implementation. Further, Sri Lankan Fire Brigade identified as poor equipped by international fire codes and standards (Daily News, 2019). However, attempts to meet the requirement without understanding the basic logic behind the law

will be laid to ineffective fire safety of the building (Abraham & Stollard, 2002). Table 1 presents the differences between policy and actual fire situations.

Table 1: Contradictions between considerations in policy and actual fire findings

Considerations in policies	Knowledge developed from experiments and incident evaluation	Source
Standard fire curve define the fire growth, not the building design and materials or the function of building	Fire growth is based on building design and materials (combustion of synthetic materials supported to ultra-fast fires).	Kobes et al. (2010)
Occupants escape through the nearest emergency exit	Occupants typically use the familiar exits and rarely through emergency exit routes. (Evidence provided that familiar routes are quicker than unfamiliar routes)	Li and Zlatanova (2007) Abraham and Stollard (2002)
People who are mobile can escape without any help	Many occupants are not self-reliant, they may need some degree of assistance	Park et al. (2014)
Occupants escape quickly after hearing a fire alarm	Generally occupants more quickly response to verbal signals ambiguous, especially people in groups commonly ignore the uncertain fire alarms.	Kobes et al. (2010) Abraham and Stollard (2002)
Occupants use exit route signs to find the nearest exits	Assessment of four-hundred (400) cases shows that around 95% of survivors were unaware of the exit route signage	Park et al. (2014)

2.4.5 Firefighting Tools and Techniques

The development of advanced fire related simulation tools to manage fire catastrophes also unable to control the uncertainties in fire prediction, detection and suppression techniques (Hasofer 2011). Even though many computer simulation fire related software have been developed, practical application is still in debate. According to Hasofer et al. (2011) many residential building's fire spread quickly due to appliances such as heating and lighting appliances, electric outlets and extension cords. Further, Daily News (2019) has identified that recent massive fire in the Kilinochchi, Sri Lanka has exposed many inadequacy in firefighting services and lack of proper equipment. Only 40 fire stations can be seen in Sri Lanka and half of them are located in the one province. Sky lifter is an essential vehicle during fire incident which is currently in

shortage. Further, Yadav (2019) has stated that Delhi, India fire department reeling under lack of equipment and staff.

2.4.6 Perceptions of architects and fire protection engineers

Park et al. (2014) have recognised communication style, language problem and over designing as common reasons for the gap between architects and engineers. Communication style is indicated that architects as 'right-brain' dominated people who start a project with a pictorial representations and or qualitative expresses, while engineers as 'left-brain' dominated people who start the project with quantitative aspects such as mathematical equations, calculation and formulas etc. When architects and engineers work together, engineers may feel that architects' expressions as imprecise expressions (Park et al., 2014). Sometimes, architects do not compromise or do not have flexibility to change their artistic ideas according to the fundamental building requirements. Sometimes, architects may play the project manager's role by monitoring the whole project from the design stage to building occupation. Generally, functional and aesthetic requirements are concerned by architects when making design decisions (Park et al., 2014). Not only that, needs of clients and other stakeholders are also needed to fulfil. Further, fire safety is one of the considerations which always draw less attraction. Some argue that architect often fail to consider fire safety even though it considered as a public requirement. For that reason, fire protection measures have been enforced in the forms of codes and standards. Accordingly, decisions of architects may need to be adjust to fulfil the codes and standards.

Park et al. (2014) identified the role of Fire Protection Engineers (FPEs) and emphasised FPEs' understanding on architects as one of the key players for fire safety. Further, authors have mentioned that architects should be informed and educated about fire safety in order to enhance the integration of architectural design on fire safety from the early design stages. On the other hand, FPEs also should be aware on effect of design features on fire safety in order to decide mitigation strategies. Moreover, authors have identified that FPEs involvement in late design stage, will be resulted in less or poor fire strategies involvement in building design. Accordingly, FPEs need a holistic understanding of building fire safety including building's physical performance, design features, building occupants and fire system in order to identify

their influencing behaviour on each other. Even though, engineers are finding means to mitigate the impact of fire disasters, their frequency seems to be increased. Accordingly, FPEs and architects conduct their role with dissimilar perspective on the occupant, building and fire components.

2.5 Hardware and Software Measures of Fire Safety

Leaning from previous building fire incidents, various nations have executed numerous fire safety measures. Fire safety system of a building is designed with the aim to reduce the effect of fire in the building aspects in terms of likelihood and consequences. A fire safety system of building can be considered to confirm fire safety within the building where the fire is initiated and outside the building where the fire is initiated. Early fire detection is very important as preliminary firefighting method. Primary objective of fire detection system is identification of fire (in terms of smoke, heat or flame) and transfer those signals to fire alarm panel (Liu et al., 2012). Heat detectors, flame detectors, smoke detectors and beam detectors are some common fire detection techniques. According to Han and Lee (2009) smoke detectors are placed at the highest point of the area while considering the possibility of generating smoke. Similar to smoke detector, flame detector is considered radiant energy which is received from flame. Flame detectors are normally placed in stores or chemical stores which contain flammable chemicals (Han and Lee, 2009). Further, two types of fire detection systems can be identified as conventional system and addressable system. Both systems pass signals of call points or detectors to a main control panel but addressable system indicates the exact devices which has been activated.

Apart from that, Ultraviolet and infrared detectors, particle sampling, relative humidity sampling, smoke analysis, temperature sampling and transparency testing are known as general early fire detection techniques (Wei et al., 2013). Early fire detection is very important as preliminary firefighting method. These fire detection systems deliver emergency warning to activate fire protection system. Visual based approach for fire identification acts as the most reliable information generating method (Liu et al., 2012). Wei et al. (2013) recognised colour video technique as a method to identify fire flame from smoke. Complex hybrid system with multiple inputs from visual camera,

infrared camera, meteorological sensors and geographical information database is supported to identify forest fires (Han and Lee, 2009).

Apart from fire detection, fire protection is the other aspect of fire safety. Mutual coordination of man, machine and environment can be defined as 'safety' (Ono, 2003). Fire protection categorised as active fire protection and passive fire protection. Active fire protection measures contribute to reduce the severity of a fire and passive fire protection refers to the fire resistance elements of the building (Lin et al., 2016). But due to lack of fire management and safety sense cultivation, fire events prevailing catastrophically (Halliday & Booth, 2019).

Moreover, control the growth and development of fire in early stage as well as facilitate sufficient evacuation paths and early warnings to building occupants are considered as safety considerations within the building. Further, fire safety in outside the building is examined to limit the spread of fire, control the spread of smoke and offer sufficient structural stability to escape and allow reasonable fire brigade activities. With the above objectives and function, each of these aspects are considered as sub systems of fire safety system in detailed (Hasofer et al. 2011). Five main subsystems can be identified as control of fire ignition and development in early stage, control of flame spread, control of smoke and toxic, facilitate of means to allow occupants avoidance and provision of sufficient structural stability. Different fire safety measures can be identified for each five subsystems and the measures can be categorised under hardware and software. Physical systems that are incorporated with the building are named as hardware whereas software refers to direct or indirect influence of human on fire safety or reliability of hardware systems. Table 2 presents the measures for three subsystems.

Table 2: Fire safety subsystems and their measures

Fire safety subsystem	**Measures**	
	Hardware measures	**Software measures**
Control of fire growth and development in early stages	Material of construction	Human monitoring
	Earth leakage devices	Maintenance of mechanical and electrical systems
	Surveillance system	Trained occupants for early fire fighting

	Alarm and detection systems	Maintenance of alarm and detection system
	Sprinklers, hose reels and extinguishers	Maintenance of sprinklers, hose reels and extinguishers
	Other automatic fire suppression devices	Presence of occupants within the building
Limit of flame spread	Materials of construction including linings	Management and maintenance of alarm and detection system
	Physical barriers	Maintenance of fire barriers
	Alarm, detection system and fire brigade	
Control of spread of smoke and toxic products	Smoke exhaust system including purging	Management and maintenance of smoke exhaust and pressurisation systems
	Physical barriers	Maintenance of barriers
	Stairs or zones pressurisation system	
Facilitate means to allow occupant avoidance	Exits	Evacuation drills
	Signage	Presence of trained wardens
Provision of structural stability	Structural behaviour	Maintenance of fire protective coating
	Concrete cover and fire protective coating	
	Size of structural members	

Source: Hasofer et al. 2011

2.6 Models for Building Fire Impact Evaluation

Ouellette (1993) stated that the qualitative approaches are suitable to gain holistic understanding about the complex phenomena like building fire safety. Generic Fire Response (GFR) and Model and Integrated Characteristic Interaction (ICI) model can be identified as two main qualitative models of building fire safety.

2.6.1 GFR Model

GFR model assists various stakeholders in understanding of fire development, human response and building response (Park, 2014). This GFR model shows the relationships of people, building, and fire responses. Limitations of Fire Safety Concept Tree, such as chronological aspects of fire development, building responses, and human reactions are properly addressed in GFR model. Figure 1 depicts the GRF model.

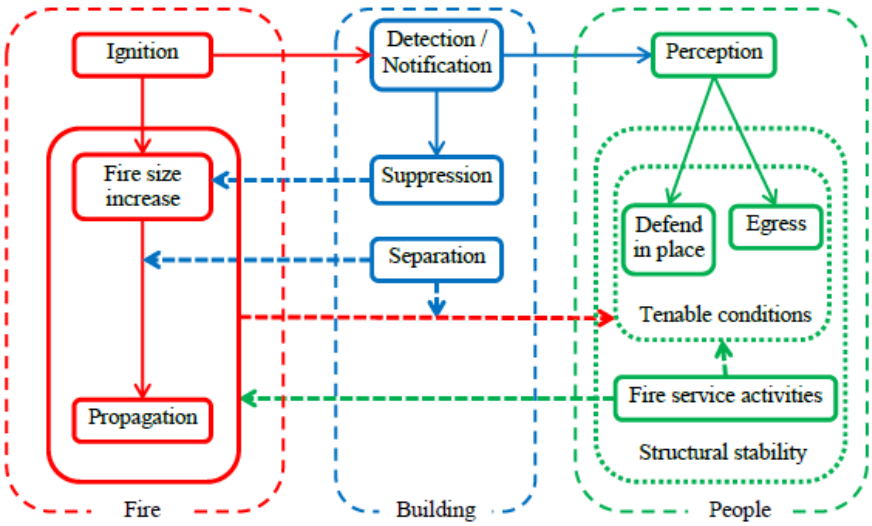

Figure 1: GFR model

Source: Park (2014)

In the GFR model, red, blue, and green colours are involved to denote the three components such as fire, building, and people, respectively (Park, 2014). Chronological event occurrence shows in solid arrows and effect of one sub-component on the other displays in dotted arrows. Red coloured fire component shows the fire development process, which comprises three aspects: ignition, fire size escalation and propagation. Detection system activated by combustion products when star ignition. Then detection system activates the notification and suppression system. Further, fire size control by suppression in order to prevent continuous combustion. Two component can be identified in separation effects, such as preventing fire spread afar the specific place of source and physically dividing hazardous fire component from people. Fire-rated building components and compartmentation are included for the fire separation (Park, 2014).

2.6.2 Consolidated Model of Fire and Smoke Transport

Consolidated Model of Fire and Smoke Transport (CMFST) is known as the world's most accurate simulation to evaluate impact of fire on the building environment (Alkhazaleh and Duwairi 2015). Further integration of CMFST to Berkeley Architectural Walkthrough (BAW) system, it delivers scientific visualisation of building condition during fire incident from the view of a person walking through a

burning building. Through the BAW system natural visual effects of smoke and flame in fire condition can be evaluated and toxic compound in the air such as hydrogen cyanide and carbon monoxide and also temperature of the walls, floor and atmosphere can be evaluated (Alkhazaleh and Duwairi 2015). These technologies can be involved to enhance the architects and engineers understanding about the building fire.

2.6.3. Fitzgerald's Building Fire Safety Evaluation Model

Fitzgerald's Building Fire Safety Evaluation Model (FBFSEM) is analysed the sequential fire growth from fire eruption to spread beyond the origin point using network diagrams (International Code Council, 2009; Satti and Krawczyk 2004). Fire Safety Evaluation System (FSES) is a component ranking model for the assessment of fire safety performance which assigns weighted points to different fire safety parameters (Park et al. 2014). Based on the FSES, some similar fire safety componentsranking methods were developed in Hong Kong and United Kingdom (Ding et al. 2006; Greenwood et al. 2010). FBFSEM and FSES can identify as models which relates with quantified values.

2.6.4. Fire Safety Concept Tree

Fire Safety Concept Tree (FSCT) is used structured tree diagram which evaluate fire safety objects as prevent fire ignition and manage fire impact (Park et al. 2014; Tubbs 2007). With the help of FSCT, engineers can easily understand the variability of different design solutions for different safety strategies (Park et al. 2014).

2.6.5 Fire Dynamics Simulator

Fire Dynamics Simulator (FDS) model which developed by National Institute of Standard Technology, analyses the behaviour of smoke and ventilation in different vent sizes of the building (McGrattan 2004). Further, FDS model with large eddy simulation can be used to analyse the thermal condition of the building (Lin et al. 2006).

2.6.7. ICT Model

ICI model denotes cause and effect relationship of fire incidents (Park et al., 2014). ICI model is identified as a supporting model to GFRM for defining specific

interaction within any scenario. To indicate the cause and effect relationship arrows are used, arrow head for effect and arrow root for cause and dotted lines between two features show that one is considered as a sub-feature of the other. Figure 2 presents an individual model which describes the relationship between fire and building characteristics.

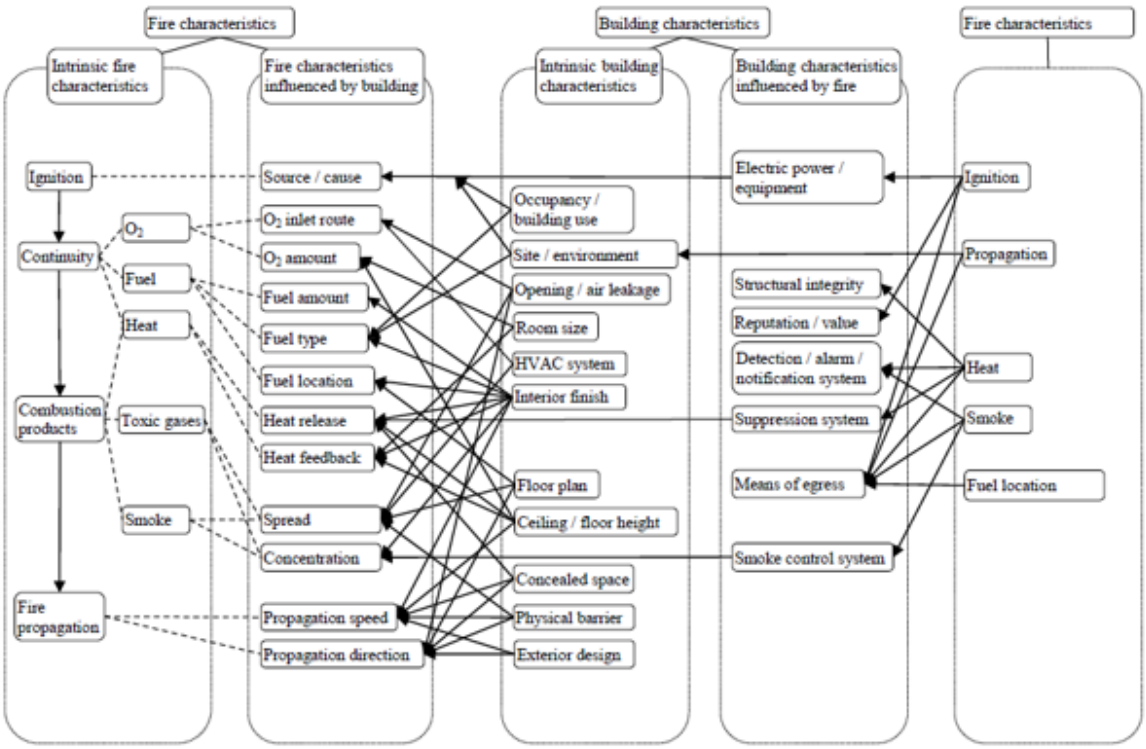

Figure 2: Relationship between fire and building features

Source: Park et al. (2014)

2.7 Building and Fire Codes

There are main two forms of building and fire codes, such as prescriptive-based codes and performance-based codes (Mora, Bitsuamlak & Horvat, 2011; WBDG, 2012). Detailed requirements based on specific building use or occupancy type describe in prescriptive codes. Fire safety design related prescriptive codes have been used for many years, but there are some arguments that these codes have lack of scientific bases for several requirements and do not facilitate fast growing building technologies and innovative design features. To overcome the issues, functional-based and performance-based approaches to building and fire regulation began to develop

(Hadjisophocleous, Benichou & Tamim, 1998). Purpose of this form of building regulation was to enable innovations, reduce regulatory burden and unwanted cost. Need for complete and well justified engineering analysis and design can be identified as the most important aspect of performance-based regulatory system (Capon, 1983; Mbamali, Aiyetan & Kehinde, 2005). Further, performance-based fire safety codes do not generally attach detailed requirements as part of the legislative document, as presents in Figure 3 (ABCB, 2005).

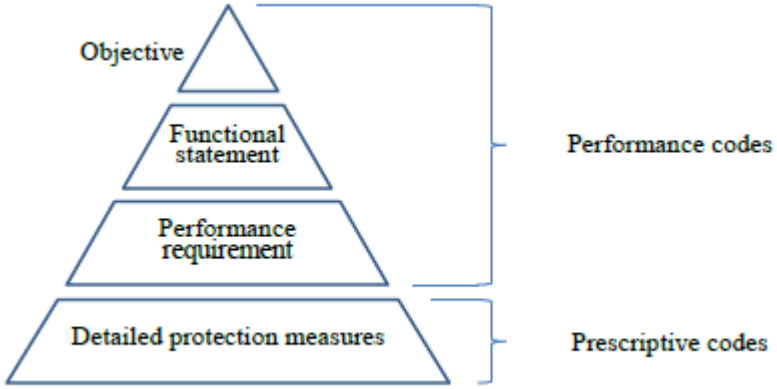

Figure 3: Relevant requirements for performance codes and prescriptive codes

Source: Park (2014)

2.8. Fire Regulations and Guidelines

Fire regulations and guidelines specify which kind of fire safety measures should be included in a specific building as a minimum requirement (Park, 2014). Main four terms are used to describe relevant rules and regulations, namely: regulations, specifications, standards and listings. Regulations can be identified as a set of rules or orders with the force of law and issued by executive authority, government or a regulatory agency. Precise statement of a requirement is a specification and standards are described as a basis of comparison or an approval model considered by an authority or general consent. Listing refers to a list which included relevant equipment, materials or services published by an organisation and alarmed with assessment of products or services. Mainly three fire regulations and guidelines are referred in Sri Lanka, namely, Code and Standards of National Fire Protection Association (NFPA), Fire Regulations of Construction Industry Development Authority (CIDA), Mandatory

Structural Fire Protection and Access Requirements of Fire Service Department and Fire Safety Requirements of Urban Development Authority (UDA).

2.8.1 Code and Standards of NFPA

NFPA has published more than 300 codes associated to fire risks (National Fire Protection Association, 2019). These codes and standards are administered by nearly 250 technical committees and used throughout the world. They have different codes and standards for mainly five topics such as Building and Life Safety, Electrical, Emergency Response, Fire Protection System and Industrial Hazards (National Fire Protection Association, 2019).

2.8.2 Fire Regulations of CIDA

Seven chapters have described in Fire Regulations in CIDA (CIDA, 2011) Namely, Chapter 1-Definitions, Chapter 2-Menas of Escape, Chapter 3-Structural Fire Precautions, Chapter 4-Fire Extinguishing and detection appliances, Alarm features and other Fire Protection Systems, Chapter 5-Special Uses, Occupancies and Structures, Chapter 6-Access for Fire Fighting Vehicles and Chapter 7-Maintenance of the Fire Protection Facilities.

2.8.3 Mandatory Structural Fire Protection and Access Requirements of Fire Service Department

Fire Service Department has introduced compulsory requirements for structural fire protection and access to be involved in proposed building plans (Colombo Municipal Council: Fire Service Department, 2017). Section A of the documents is provided information about protected stairways, alternative means of escape, firefighting shaft requirement, compartmentation, holding are, fire command centre, rules for external access and refuge floor. Apart from that, section B describes the height category of buildings and requirements as per occupancy is explained in section C.

2.8.4 Fire Safety Requirements of UDA

UDA (2018) issues requirements of fire safety compliances are when taking approvals for contracting a building. UDA’s main guidelines for fire safety in a building as follows:

- All industrial buildings, warehouses, public assembly building and high rise building which extent the installation more than 400 m^2 shall conform to any additional fire safety requirements.
- Every building shall confirm to relevant requirements of building type or the specific area.

Guidelines for fire safety requirement for factory building are mentioned as a separate section in UDA's guideline for fire safety. Even though, plenty of codes and standards have introduced, fire proof building is a major challenge worldwide. There are about over ten-thousands of these fire events every year in whole world, which have terrible impact on our whole society and take massive damages (Bukowski & Séquin, 1997).

2.9 Building Fire Statistics

In the past two decades from 1993 to 2015, around 86 million fires have occurred and more than 1 million fire deaths reported (Brushlinsky et al., 2017). According to Bulletin (2014), annual loss from global fire incidents results in about 1 percentage of worlds Gross Domestic Product. Both developed and developing nations face for average 3.8 million fire incidents and around 44, 000 fire deaths every year (Kodur, Kumar & Rafi, 2019). Accordingly, fire risk can be seen in all countries despite their economic status. Developing countries such as Pakistan and India suffered the highest number of fire causalities (10, 000 – 25, 000) per year and second highest number of fire incidents (100, 000-600,000) per year (Brushlinsky et al., 2017). Hence, Asian region is identified as the second highest region with fire safety non-compliance. Figure 4 depicts the fire safety non compliances in different regions (Sedex Information Exchange, 2013).

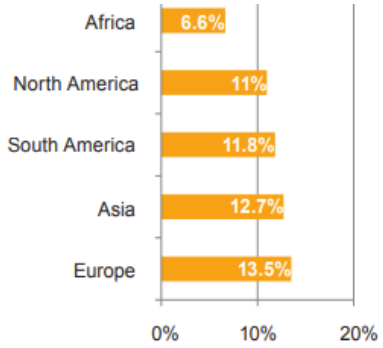

Figure 4: Fire safety non compliances

Source: Sedex Information Exchange (2013)

Sri Lanka is one of the Asian countries that frequently faced fire catastrophes throughout the history (Waidyasekara, Thilini & Dahanayake, 2013). Further, fire incidents have identified as the second highest disaster topology in Sri Lanka (Sedex Information Exchange, 2013; Disaster Management Centre, United Nations Development Programme in Sri Lanka, & United Nations Development Programme Regional Centre, Bangkok, 2009). Sri Lanka National Report on Disaster Risk, Poverty and Human Development Relationship-2009 has reported 2703 major fires between year 1974 – 2007 (Disaster Management Centre, United Nations Development Programme in Sri Lanka, & United Nations Development Programme Regional Centre, Bangkok, 2009). Accordingly, built environment in Sri Lanka is faced critical fire incidents due to numerous reasons. Fire Brigade in Colombo has only one aerial ladder which can extend up to eighteen floors and fire pumps can of reaching up to seven floors only (Daily News, 2019). Further, Sri Lankan Fire Brigade identified as poor equipped by international standards and lack with quick response (Daily News, 2019). Lack of quick response can be identified as the reason for recent fire event happened in Kandy (Daily News, 2019). In Sri Lankan history, Central Bank bomb explosion resulted to major fire event which resulted to severe damages. Even though the present technology is in high end; fireproof buildings are still a worldwide solution seeking problem (Liu et al., 2012).

2.10 Fire Incidents in Apparel Manufacturing Sector

Considering fire issues in different sectors, the highest number of non-conformities were reported in manufacturing sector among all the other sectors in each region

(Sedex Information Exchange, 2013). Figure 5 depicts the fire safety non-conformities in different sectors worldwide.

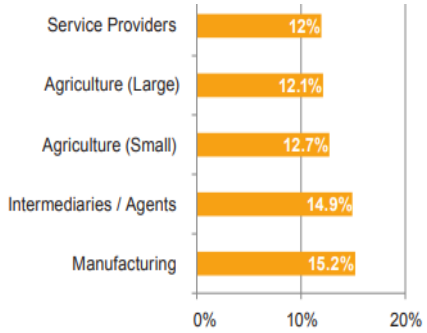

Figure 5: Fire safety non-conformities in different sectors

Source: Sedex Information Exchange (2013)

Figure 6 presents various global health and safety non-compliances in manufacturing sector. According to the Figure 6, fire safety non-compliance is the highest portion as thirty two percentage (32%).

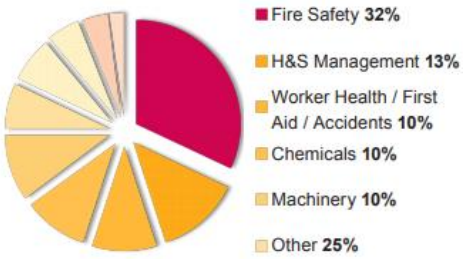

Figure 6: Global health and safety non-compliances in manufacturing sector

Source: Sedex Information Exchange (2013)

Moreover, when considering about different sectors in manufacturing sector, apparel manufacturing sector represent a significant role. Apparel manufacturing sector is one of the significant contributors in the national economy of many countries (Li, Xu, & Li, 2016). According to Singh and Khajuria (2018), apparel manufacturing sector is one of the fastest growing industrial sectors in world, while providing millions of job opportunities to the world economy. The apparel and fashion industries are the avenue of choice for most developing countries in their pursuit to industrialisation (Kim, Traore, & Warfield, 2010). The transition of the apparel sector has helped many

developing countries to become dominant suppliers in the world apparel market. For example, in the mid-1960s, developing countries contributed just 25% of global exports of apparel, growing to more than 70% by 2014 (Alam, Selvanathan, Selvanathan, & Hossain, 2019).

International Labour Organisation (1996) identified that over the last 25 years, the apparel manufacturing sector has changed drastically due to job losses in developed countries. As a result, the industrial production facilities from developed countries are migrating to developing countries in order to reduce labour costs (Nayak & Padhye, 2015). Moreover, the authors explained that, these developing countries face challenges in having low labour fee, low level of predictability, rapid market changes, spite of the cheap labour cost, due to the short production life cycle, high volatility and impulse buy or purchase. As a solution, the apparel manufacturing sector in developing countries uses low cost raw materials and low cost delivery options due to the higher availability of the labour resources. Therefore, most of the industrialised countries shifted their apparel products to developing countries such as China, Vietnam, Bangladesh, India, Pakistan, Africa and Sri Lanka to enjoy the advantage of nontariff barriers (Alam, Selvanathan, Selvanathan, & Hossain, 2019).

Export Development Board (2012) declared that Sri Lankan apparel industry is the largest and the most diverse contributing member to the economy of the country, as it becomes the primary foreign exchange earner as 40% of total exports and 52% of industrial exports. Due to the favourable developments in GSP + scheme, the apparel subsectors contributed to seventy-eight percentage (78%) of the total growth in the manufacturing sector in year 2018 (Central Bank of Sri Lanka, 2018). Despite the potential for further expansion of local apparel and textile industries, the lack of economies of scale, infrastructure constraints, labour turnover and high input costs are directly affecting to the entire industry competitiveness.

Apparel industry is a highly competitive industry, which is mainly focusing to reduce the cost of the product rather than the safety conditions of the workplace and workers (Wadud & Huda, 2014). Generally, there are thousands of workers employ in the factories and most of them are female workers (Raaz, 2016). Moreover, the author

emphasised that manufacturing sector dangers come from different sides and most of them are undisclosed and unexpected. According to Islam and Roman (2019), fire hazard is the ongoing problem in the apparel industries of the country over the past decade.

In 2012, nearly 112 workers were killed by a fire at Bangladesh's Tazreen Fashions factory due to the building's short circuit on the ground floor (Prentice & Neve, 2017). Thereafter, the fire quickly spread through to the nine floors, where factory workers were trapped because of narrow or blocked fire paths and many of them died inside the factory. Moreover in 2013, fire broke out at the Tung Hai Sweater Factory in the Mirpur district of Dhaka and 8 people were died (East Asia Pacific, 2013). East Asia Pacific (2016) discovered that a fire that erupted the garment factory in New Delhi, India caused to kill at least 13 workers. Also, there was a fire occurred in the garment factory in Karachi, Pakistan and 289 people were died due to unavailability of fire exits to evacuate from the building (Shoaib, 2012).

According to Export Development Board (2014), there are around 300-350 manufacturers of apparel and Brandix Apparel Ltd, MAS Intimates (Pvt) Ltd, Hirdaramani International Exports Ltd, MAS Active Trading Pvt Ltd, Bodyline Pvt Ltd, Smarts Shirts Lanka Ltd, Omega line ltd etc who are the key players in Sri Lanka. Several fire incidents can be identified from the Sri Lankan apparel manufacturing industry too from the past decades. In 2015, there was a fire occurred in the Sri Lanka Brandix apparel factory located in the Board of Investment's export processing zone in Katunayake near the international airport (Sustainabilty Report, 2017). The entire facility was damaged, with massive losses and destructions to production equipment, machinery and raw materials. According to the reports, fire detection and alarm systems have been out of order and ineffective, shut-down protocols were not properly implemented and fire-watching duties were not performed properly by security personnel in the event of the fire. Apart from the key apparel manufacturing factories in Sri Lanka, there were many fire accidents reported from unpopular apparel manufacturing companies such as fire accident at a garment factory in the Sadalankawa area in Pannala due to the accidents of service trucks (MTV Channel Private Ltd, 2019), fire event in the warehouse of a garment factory in Muthuraja

Mawatha in Wattala and the fire broke out at a garment factory in the Ratmalana area (MTV Channel Pivate Ltd, 2015).

When considering about the business nature in apparel manufacturing sector, apparel manufacturing buildings deal with fabric materials which are highly flammable. Also, large number of employees work in apparel manufacturing buildings (Lanier Pence et al., 2003). Wadud and Huda (2016) reported number of fatal accidents in apparel manufacturing sector which shows the significant impact of fire in this sector. Hence, fire risk is common in and directly affects to apparel manufacturing sector too.

2.11 Causes and Consequences of Fire in Apparel Sector

Fire is a chemical reaction of oxygen, air and fuel, which is harmful for people and the property (Science Learning Hub, 2007). There are several factors, which can be identified as the causes for the fire events in the apparel manufacturing sector. The following figure 7 summarizes the causes, which are affected to generate the fire in the apparel industry.

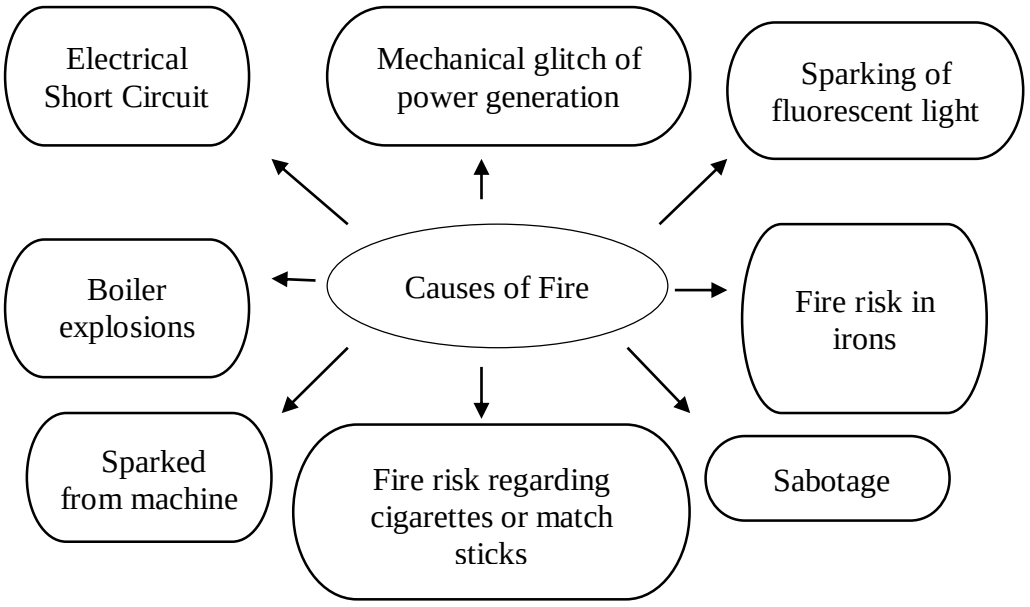

Figure 7: Causes for fire in apparel manufacturing sector

Source: (Mizanuzzaman, 2016)

Among those identified causes, electric short circuit is the prime cause of fire in most of the apparel factories (Islam & Roman, 2019). Azad et al. (2018) further declared that, the electric short circuit and boiler explosions were the major cause of fire disaster. The authors further clarified that the lack of emergency exit paths, absence of safety signage, inaccessible staircases, suffocation, and scarcity of emergency light significantly increased human causality during most of the fire incident. Moreover, many industrial plants in the apparel industry had no fire control system, about 70% of the industry had no emergency exit, 75% of the industry had no underground reservoir and only 5% of the industry had enough fire extinguishers (Islam & Roman, 2019). More than 90% of the industry does not have a fire control system, while only 5% of the employees have first aid training (Azad et al., 2018).

A fire risk is any circumstance, where the risk of fire damage to people or property is greater than normal, while it can be caused to negatively affect people's lives (Shakil, 2016).The following Figure 8 illustrated the consequences of fire in an apparel manufacturing sector.

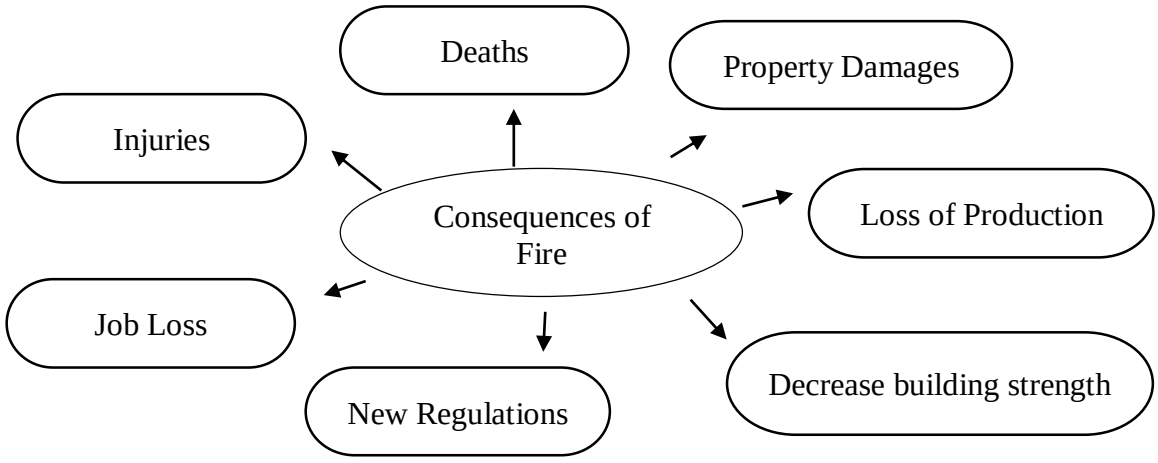

Figure 8: Consequences of building fire

Source: (Shakil, 2016)

Further, these consequences of fires in apparel manufacturing buildings specially, property damages, structural collapses and decrease building strength lead to building refurbishments which perform as an initiative to reinstate the building condition as well as to improve the quality of life within the building.

2.12 Refurbishment of Building

There are mainly four stages in the building life cycle, constitute with construction (construction process stage), operation (use stage), maintenance and demolition (end of life) (Chan, 2014). Apart from that, BS EN 15978 has elaborated the life cycle into five stages, such as product stage, construction process stage, use stage, end of life and benefits and loads beyond the system boundary (BS EN 15978 Standard, 2011). Figure 9 presents the stages of building life cycle.

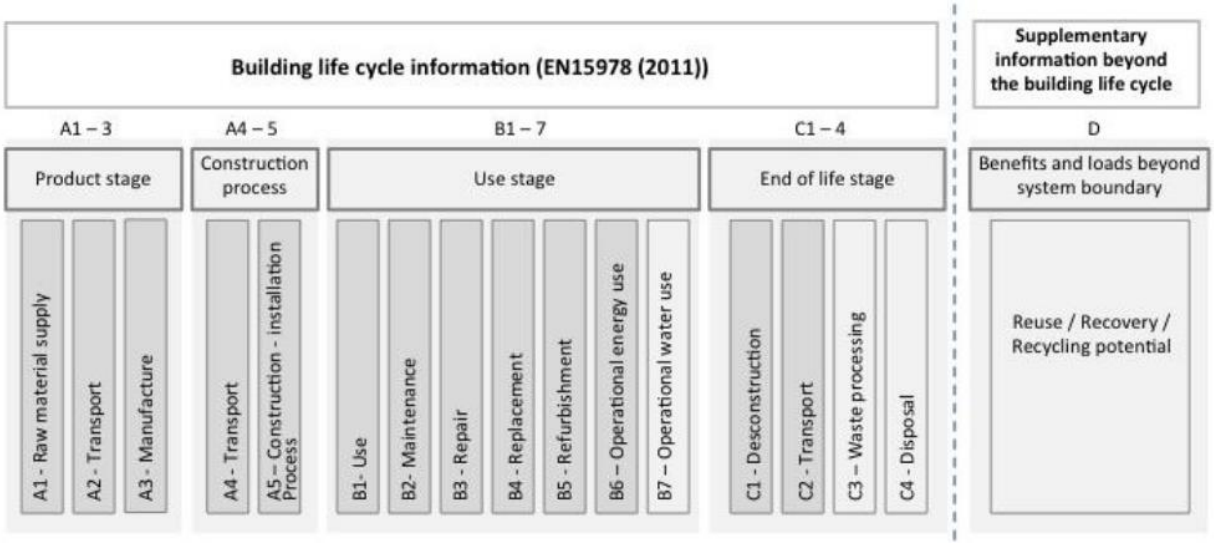

Figure 9: Building lifecycle

Source: Gomes et al. (2014)

According to the Figure 9, refurbishment occurs at the use stage of the building life cycle. Several authors have described the word of "Refurbishment" in several ways. The Table 3 shows the definitions of refurbishment.

Table 3: Definition for refurbishment

Definition	Source
Upgrading the performance of an existing building to meet new requirements.	(Ishak, Ibrahim, & Azizan, 2018)
Increasing the useful life of existing buildings to provide a new or updated version of the original structure by adapting their basic forms. Renovation of buildings involves providing old buildings a new purpose with upgrades and reconfigurations.	(Riley & Cotgrave, 2011)

Upgrading, alteration, extension and renovation of existing building for advanced facilities	Rahmat and Ali (2010)
Physical process of repair, replacement and renewal which are not precisely distinguished	Mansfield (2009)
Inclusion of improvements, adaptions, upgrading, rehabilitation, restoration, modernisation, conversion, retrofit, and repair but exclusion of cleaning, decoration and emergency maintenance.	Egbu et al. (2002)

Even though there are slight differences of above various definitions, Vilches et al. (2017) have illustrated terms; refurbishment, repair, retrofitting, restoration or renovation are used to describe refurbishment. Accordingly, refurbishment can identify as a broad term which covers several attributes which are difficult to identify their physical boundaries (Mansfield, 2009). The attributes are; expansion and extension, upgrading, remodelling, renovation, modernising, conversion, retrofitting, replacement, repairing, rehabilitation, alternation and reconstruction.

These refurbishment works can be divided in to two types, such as repair and renovations of the building (Ronayne Construction LTD, 2018). Renovation involves removing an existing or obsolete feature and replacing it with an entirely new feature, while a repair is to modify an existing or old home feature to restore it to its original level of performance (Real Estate & Mortgage Insights, 2018).

As a substitute of demolishing buildings, which are no longer used, it may have a potential to refurbish them for another use. Changing the use of existing buildings could keep existing neighbourhoods populated and safe in the future (Gillott & Spataru, 2010). Refurbishments or conversions will include specific requirements to be taken into account including the building upgrades such as fire precautions, hygiene, access to and use of buildings, storage facilities.

Building refurbishment requires to make more space, decrease energy usage and maintain our cultural inheritance while updating the building to the current standards (BRE Centre for Sustainable Products, 2010). There are adequate reasons for doing a renovation or refurbishment in buildings. Among them, the improvement of the living and working comfort and indoor climate are very important. Moreover, it can reduce the energy wastage and have financial benefits. There are obvious areas, where the

regulations will apply when performing either a renovation or a conversion, such as making a structural change or providing new drainage.

2.13 Reasons for Building Refurbishment

Refurbishment occurs when building fail to perform its expected use (Ali, Kamaruzzaman & Salleh, 2009). Kohler and Hassler (2002) have identified the escalating trend of aging building stock which leads to high demand for refurbishment projects. Generally, refurbishment provides solutions to physical deformation in buildings (Mansfield, 2009). Depend on the parties involved in the project, refurbishment decision also vary with their need and requirements (Aikivuori, 1996; Konstantinou & Knaack, 2013). Further to them, building owners expect investment benefits from the refurbishment, users expect well operation of the building while society expect welfare and other environmental benefits. According to Arain (2005) reasons for building refurbishment are:

- Corrective refurbishment
- Space altering refurbishment
- Optimising refurbishment
- Pleasure refurbishment
- Opportunity refurbishment

2.14 Timeframe to undertake refurbishment

According to Chan (2014) refurbishment need to be perform in order to maintain the building and sustain its value because building is physically deteriorated over time. Babangida (2014) has pointed out the need of refurbishment to fight against different type of building obsolescence. Figure 10 shows the time period for refurbishment against life span of building.

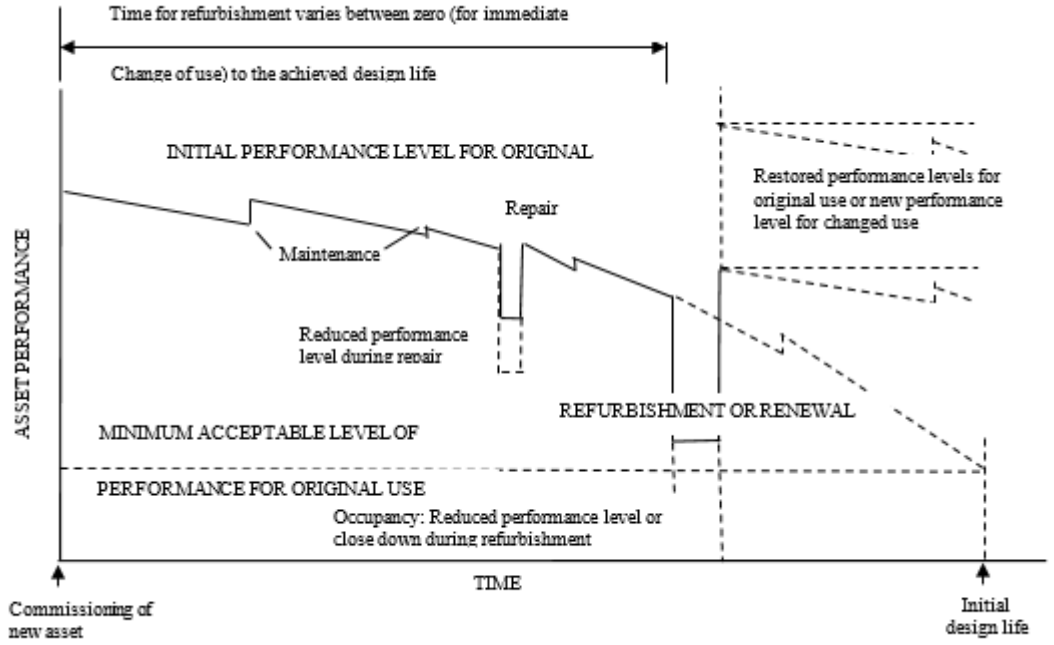

Figure 10: Time period for building refurbishment

Source: CIRIA Report (1994)

2.15 Phases of a Refurbishment Project

Any mainstream systematic guideline on phases of refurbishment project are absence due to lack of information in past refurbishment projects (Oregi, 2016). Hence, CIRIA Report (1994) has endeavoured to come up with main phases or stages of refurbishment project such as: project identification stage, project appraisal stage, project definition stage, detailed design stage, implementation stage and operation stage. Further, Ali. Kamaruzzaman and Salleh (2009) have recognised inception, schematic design, detailed design, and submission of drawing for approval, preparation of contract and implementation on site as the stages or phases of refurbishment project. Apart from that RIBA Plan of work arranges building process into eight phases which is more appropriate as a guideline for new construction since the un-matching ways in new builds and refurbishment (Rahmat & Ali, 2010). According to above three studies, phases or stages of refurbishment project can be shown as in Table 4.

Table 4: Phases/ stages of refurbishment project

Source	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Stage 8
Ali, Kamaruzzaman and Salleh (2009)	Inception	Schematic Design	Detailed Design	Submission of Drawings	Preparation of Contract	Implementation On Site		
CIRIA Report (1994)		Project Identification Stage	Project Appraisal Stage	Project Definition Stage	Detailed Design Stage	Implementation Stage		
RIBA Plan of Work 2013		Strategic Definition	Preparation and Brief	Concept Design	Developed Design	RIBA Plan of Work 2013	Handover and Close Out	Strategic Definition

2.17 Challenges of Refurbishment Projects

Lund, Haddadi, Lohne & Bjorberg (2016) have stated that refurbishment projects are contacted with different challenges which should overcome by building owners and other interested parties. Table 5 presents the major challenges in refurbishment project.

Table 5: Challenges in refurbishment project

Challenges	**Sources**														
	Ali et al., 2009	Arain, 2005	Babangida, 2014	Bryde & Schulmeister, 2012	CIRIA, 1994	Egbu et al., 2002	Jensen & Maslesa, 2015	Juan, 2009	Konstantinou & Knack,2011	Lee, 2015	Lund, Haddadi, Lohne, & Bjørberg, 2016	Mansfield, 2009	Rahmat et al., 1998	Rahmat & Ali, 2010	Sodgar, 2013
Undamaged elements/ materials may subject to degradation			✓												
The impact of noise, vibration, fumes and dirt					✓										
Potential future usage of existing elements may remain uncertain			✓									✓			
Absence of a proper site survey to investigate existing conditions of the building			✓									✓			
Lack of suitable materials to match the existing conditions of the building			✓				✓								
Accumulation of salvaged materials through demolition waste													✓		

Introducing changes to existing structure is limited	✓	✓	✓	✓	✓				✓		✓				
Insufficient design information with the unavailability of original drawings and construction details		✓	✓	✓			✓					✓		✓	
Unanticipated cost overruns and financial constraints		✓						✓		✓	✓				✓
Unanticipated time overruns		✓			✓	✓					✓				✓
Lack of information on requirements of the client				✓						✓	✓				
Unsafe working conditions			✓		✓							✓			
Lack of proper communication and coordination between the project participants					✓	✓	✓								
Lack of specialised knowledge and multidisciplinary skills from the project participants						✓	✓			✓					
Legislative constraints			✓		✓										✓
Lack of quality standards and parameters											✓	✓			

2.18 Refurbishment of Fire Damaged Buildings

Refurbishment of fire damaged buildings should have a standard process with regular supervision especially in apparel sector in a cost-effective manner. Fires can vary size and the damage they cause (Rise, 2008). Accordingly, there should be a particular process for reconstruction of fire damaged building.

At the initial stage, the damaged building should be fully cleaned. Specialised cleaning and building contractors use ozone machines and thermal foggers that can eliminate the effects of fire induced odours in appreal sector buildings (Hutton, 2019). The main requirement of refurbishment process is that taking the approvals of the relevant authorities such as municiple fire comission. The inspections are carried out to determine the appropriateness of refurbishment works. Whenever a foundation-exclusive building or structure shows 33% or more damage or deterioration to its supporting member or members of 50% damage or deterioration to its non-supporting members, enclosures or outside walls or coverings, the Joint Municipal Fire Commission has jurisdiction to declare the building as dangerous and to suggest repair, vacation or demolition (River, 2014). Moreover, drawings and specifications should be examined and approved.

Fire damage restoration should be done as the next step with- the proper cordination between the design team including architects, engineers, facilities managers and the client. The team should identify the client's requirements in refurbishing and should focus on minimising the similar kind of tragedies. The reconstruction process should include drywall replacement, painting, carpet or floorboard removal and installation, and even major carpentry and remodeling projects (Paul Davis Corporation, 2014). There are few things to be considered about usage of materials while the reconstruction. There should be a proper understanding over what structural framings being replaced and what is being just painted and cleaned. Smoke ceiling aluminium painting must be done carefully. The roof needs to be repaired with sealed rafters and cladding to make the smells disappear (Rise, 2008). The author further highlighted that all the works need to be done according to the highest standards within the estimated time and cost constraints.

Generally, buildings carryout evaluations to identify the critical problems in the building performance (Preiser, 1995) . Post Occupancy Evaluation (POE) is one of the methods used to assess the performance of a building after it has been built and occupied (Hansen & Leo, 2017). POE mainly focuses three broad themes; process, functional performance and technical performance (Blyth & Gilby, 2012). Under the functional performance, it assess the BPMs, life cycle cost, operational management and strategic values. There are number of techniques such as walk through observations, interviews, focus group, workshops, questionnaires, measurement and physical monitoring which are used to evaluate the building performance.

2.19 TBP

Providing comfort to the building occupants is the main essence of a building (Celik, 2010). Therefore, the concept of TBP was developed within Public Works Canada, Architectural and Building Science Directorate between 1981 and 1985 (Huang & Niu, 2016). Over the years, TBP has been a vital concept among many researchers and industry practitioners (Wong and Jan, 2003). Almost 90% time of developed countries' people spent in indoor building environment and therefore due consideration should be given for its performance (Frontczak and Wargocki, 2011). Integrating this TBP thinking to building design as well as to operation, we can reduce pollution, waste and energy consumption as well as to enhance quality of life within the building (Hartkopf & Loftness, 1999). Within the setting of built environment, four conditions should be emphasised for the ultimate success of the application of building performance.

2.19.1 Occupant Satisfaction

Occupant satisfaction refers to the fulfilment of physiological needs, sociological needs and psychological needs (Brager & Baker, 2009). Ergonomics or spatial needs, air quality, thermal requirements, acoustic comfort and visual quality are concerned under occupant satisfaction. Apart from that, occupants have dissimilar requirements at various occasions, hence 'one size fits all' concept is outdated. Therefore, individuals' sociological and psychological requirements must be also identified when conduct building operation.

2.19.2 Organisational Flexibility

TBP should concerns about organisational requirements, such as adhere to global competitiveness, rapid hierarchical changes, advance technology adoptions, diverse customer requirements etc. (Adonisi, 2005). TBP concept must be aligned with organisational day to day practice and also should design to promote workplace comfortability among all occupants.

2.19.3 Technological Flexibility

Building structure and its operations should adhere to rapid technological changes while accomplish continuous development, especially in data and telecommunication services (Gosling et al., 2013). Not only that, advance technologies should integrate to the building operation to have a better building performance, since it helps to evaluate TBP in various aspects.

2.19.4 Environmental performance and Energy Efficiency

Building design and construction, operation, maintenance, refurbishment and demolition should be performed by considering environmental impacts and energy usages (Hense & Lamberts, 2012). To have a better building performance, total environmental and energy footprint should be minimised.

2.20 BPMs

TBP can be evaluated and measured through BPMs. According to Celik (2010), BPMs play a vital role in providing comfort to the building occupants. Mandates can be described by using two different aspects: fundamental mandate (refers as building enclosure integrity which protect building's visual, mechanical and physical properties from environmental degradation) and set of BPMs related to occupancy requirements and comfort (thermal, acoustic, visual, air and spatial). According to Wong and Jan (2003), these occupant related mandates are depend on physiological, psychological, sociological and economic values. TBP is a framework of subjective and objective evaluations in all performance mandates (Wong & Jan, 2003). TBP measure and evaluate by six BPMs. BPM provides comfortable environment for building occupants and support for their well-being (Pheng Low et al., 2012). Five BPMs present as follows:

1. SP
2. TP
3. IAQP
4. VP
5. AP

2.21 SP

According to Pheng Low et al. (2012), spatial arrangement is an essential component for every building and should consider, the work performed, equipment used, no. of occupants and storage requirement (Wong and Jan, 2003). SP concept is known as a functional performance concept and also this area has relatively low studies and researches when compare with other performance mandates (Pheng, Ying & Hiong, 2008). In general, main concern of SP mandate is to evaluate ergonomics considerations of a space to gain optimum fulfilment to the respective occupants (Pheng, Ying & Hiong, 2008; Waldman and Spangler, 1989; Danielsson, 2019). Further, authors have informed that spatial arrangement of a working area is directly affected to health conditions of people who are working there. Not only have that, the special performance will directly impact on the quality as well as quantity of their work (Wohlwill and Weisman), 2012. Especially, Pheng, Ying and Hiong (2008), have identified that high quality working area as a plus point for greater performance. General segmentation in the office space is comprised with a special cabin to managers and other superiors who job in the clustered office. Thus this arrangement supports to observe workers' performance more effectively and easily. Moreover, a great layout of apparel building is directly associated with workflow or material flow chart. Feeding the relavant materials at highest possible speed and in one direction without any overlaps and provisions for future expansions need to be considered in the space arrangement of a apparel factory (Danielsson, 2019).

Further, four acceptability limits (detailed explanation in heading 2.4) directly applied with spatial performance. Psychological requirements of spatial performance concern about conditions which affects to privacy and distractions. Further, psychological requirements should be concerned about space arrangements with individual privacy requirements. Second one is physiological requirements and it more towards to spatial

performance with ergonomics comfort. Not only that, physiological requirements must be ensured the functional requirements of the space while fulfilling all the other service requirements. Especially, in this second requirement, building must design by considering disable occupants' needs and wants. Sociological requirements in special performance concerns about individuals' needs such as proper communication and interactions. Space arrangement should properly facilitate communication needs of occupants. Last limit of acceptability is economic requirements. Economic requirements for spatial quality must be covered through proper arrangement of space while maximise benefits to building owner and occupants. Building designers try to maximise renting space or usable space out of available gross floor of the building in order to maximise economic benefits.

2.21.1 Guidelines of SP

Apart from that, there are main five guidelines, which have drafted by considering above four acceptability requirements.

1. Reaching ergonomic comfort

   Basic idea of ergonomics is to fulfil occupants' comfort requirements. Sometimes building designs cannot be fulfilled all the ergonomic requirements of the occupants but theory identifies that ergonomic comfort is to fulfil the comfort requirements of majority (Dumesnil, 2019).

2. Safeguarding privacy

   Privacy is a key aspect which is everyone need. Building occupants do not prefer any disturbances to their privacy. Building designers can show the trust by providing enough privacy to the working spaces and this can improvement productivity of the occupants. Simply, partitioning using cubicles of working space can be identified as the simplest way of giving privacy (Inkeles, 2010).

3. Space conservation

   In workplace, space can identify as a limitation and only limited area vacant for use. Thus, building designers try to provide reasonable space for the occupants while maximising profit for the use of space (Inkeles, 2010).

4. Systematic arrangement of space

Available space of building should be arranged in a systematically, on the other hand, non-systematic space arrangement leads to confusion. Further, systematic arrangement of space will lead to more neat and attractive working spaces for their occupants (Aronoff & Kaplan, 1995).

5. Collaboration between users

   Space must promote human interactions and should not prevent their communication. Accordingly, walls that use to separate space should not limit human interaction or should build more avenues to have occupants' interactions with one another (Aronoff and Kaplan, 1995).

2.22 TP

The condition of mind, which express the satisfaction with the thermal environment is referred as thermal comfort or TP of the building (American Society of Heating Refrigerating and Air Conditioning Engineers [ASHRAE], 1981). Thermally comfort means occupants may feel neither warmer nor cooler. TP mandate refers to three components; temperature, relative humidity and air movement (Pheng Low et al., 2012). Further, Frantczak and Wargocki (2011) explained that thermal environment is a combination of four physical variables (air temperature, mean radiant temperature, relative air velocity and air humidity) and two variables related to people (clothing and active level). TP affects occupants' sense of warm or cool and also dry or humid (Huang, Zhu, Quyang & Cao, 2012). According to ASHRAE (2004); Bsen (1995) Predicted Mean Vote and Predicted Percentage Dissatisfied which are based on Fanger's comfort equation are commonly used for access thermal comfort. Acceptable limits of thermal performance is differ from place to place. As stated by Wong and Jan (2003) general non –conditioned area has temperature (24–28 ^{0}C), relative humidity (20-70%) and average air movement (< 0.8 m/s). Further, severe microbial and IAQ problems can be happen due to high space relative humidity (Pheng Low et al., 2012). Occupants feel discomfort and lose their attention in moments which air movements beyond the recommended range. According to Wong and Jan (2003) during or after a fire event, small movements of building caused as a result of the thermal displacements.

Fanger's PMV-PPD model for thermal comfort had integrated with ISO Standard 7730 by modifying several scientific consensuses (Fanger, 1982). This implication directs to the prediction of thermal sensation as a function of internal temperature, humidity, air velocity and mean radiant temperature.

2.22.1 Indicators for TP

- **Frequency of the operative temperature**

Frequency of the operative temperature (FOT) identifies the most recurrent temperatures for a particular space (Sicurella, Evola & Wurtz, 2012). Further, FOT is useful in comparing operative temperatures with those acquired with other building solutions such as, shading and insulation etc. Experts have recommended to conduct daily basis analysis for operative temperatures especially when evaluating the movable shading devices. Moreover, FOT has not identified as a regulation strategy for thermal performance because it absents in evaluating the actual time of operative temperatures occurs.

- **Frequency of thermal comfort conditions**

Frequency of thermal comfort conditions (FTC) indicates the ratio of time within a given time period during indoor thermal comfort conditions are accomplished. This FTC refers to three ranges and these ranges should be complied with thermal comfort criteria (British Standard Institute, 2007).

- **Intensity of thermal discomfort**

Intensity of thermal discomfort (ITD) is referred to the difference between current operative temperature and the upper limit of comfort or the lower limit of comfort. ITD is quite similar to the term integrated discomfort degree (Zhang et al., 2006). Discomfort in terms of over cooling or over heating can be seen in high ITD situations. When calculating ITD in some buildings such as offices and schools, correct time period should be selected in order to have better integration.

- **Fluctuation of thermal discomfort**

Fluctuation of thermal discomfort (FD) is defined as a way to distinct different situations of frequency of thermal discomfort (FTD). Further, FD can be defined as a ration of the ITD to the measurement of time period when thermal discomfort is occurred.

According Oral, Yener and Bayazit (2004), thermal comfort assesses by considering indoor air temperature, indoor humidity, inner surface temperature and air flow within the given space. Most of the international standards, thermal comfort is defined as a quantitative form with respect to different standards. ASHRAE Standard 55-81 is discussed about the suitable indoor air temperature conditions of a particular space with regards to room function, activity level and properties of the user (American Society of Heating Refrigerating and Air Conditioning Engineers, 1981). Apart from that, ISO Comfort Standard is also validated as another standard regarding thermal comfort conditions (International Organization for Standardisation, 1983).

2.23 IAQP

According to United States Environmental Protection Agency's comparative risk studies, indoor air quality is ranked as one of the top five environmental risks related to public health (Lai, Mui & Wong, 2009). IAQP is directly influence to the core function of apparel buildings, because poor air quality effect on low productivity (Nazaroff, 2013). In past year, questions regarding air tightness of the building was raised as a focus of air quality and occupant health (Nazaroff, 2013). Efficiency of ventilation is measured by the level of carbon dioxide prevailing in the building space. According to ENV Guide-lines, suitable level of carbon dioxide is 1000 ppm for indoor space (Kinnear, 1986). Carbon dioxide concentration beyond 600 ppm may cause physical effect, such as sensation of breathing difficulty, fatigue drowsiness and lack of concentration (Nazaroff, 2013). Moreover, allergic asthma can be recognised as one of the common health complaint regarding IAQ and suspended particular matter can be identified as the core reason for asthma (Kinnear, 1986). Table 6 presents the common indoor pollutants, sources and potential health effects.

Table 6: Common indoor pollutants and sources

Indoor Air Pollutant	Source	Potential Health Effects	Measures to Improve IAQ
Carbon dioxide	Breathing Tobacco smoking Combustion sources	Causes sleepiness, headaches, dizziness and nausea at high level	Provide fresh air supply and ventilation
Carbon monoxide	Combustion sources Exhaust Tobacco-smoking	Causes fatigue, headaches, rapid breathing, chest pain. Decreased alertness	Avoid combustion in indoor environment Provide separate exhaust system
Nitrogen dioxide	Combustion sources Exhaust Smoking	Causes irritation to eyes and respiratory system	Avoid burning in indoor Maintain sufficient ventilation
Formaldehyde	Pressed-wood products Adhesives Urea-formaldehyde foam insulation Incense burning	Causes irritation to eyes and respiratory system Lung damage at high level	Avoid using pressed-wood products Maintain sufficient ventilation
Respirable suspended particulates	Combustion sources Photocopiers and printers	Causes irritation to respiratory system, eyes and noise Allergic reactions	Clean and vacuum Use air purifier
Biological contaminants	Dirty air ventilation system Growth in damp and dusty environment	Sneezing, watery eyes, shortness of breath, lethargy, fever or asthmatic reactions.	Keep premises clean and dry Keep good hygiene and good ventilation
Volatile organic compounds	New furniture Renovation materials Pesticides, cosmetics	Irritation to eyes, nose and throat Headaches, dizziness, visual disorder	Use low emission renovation materials Limit use of VOC-containing products
Radon	Concrete building materials which contain granite	Lung cancer	Involve sealant to cover up concrete materials
Ozone	Photocopiers, laser printers and fax machines Air purifiers with high voltage discharge components	Irritation to eyes and respiratory system, and chronic respiratory disease	Isolate ozone emitting machines Use exhaust gas system

Source: (Salthammer, 2019; Schibuola & Tambani, 2020; Weschler, 2009)

2.24 AP

Acoustic comfort is known as the condition of contentment with sound parameters (Navai & Veitch, 2003). On the other hand, noise is defined as unwanted sound that

leads to annoyance in the working space (Low, Liu & Oh, 2008). Especially this acoustic concept deals with noise and vibration. Unwanted sound, which identify by listener can be named as noise and noise is mainly defined on listeners' subjective behaviours. Accordingly, sound appreciated by one person may be frustrating sound in another (Aronoff & Kaplan, 1995).

AP refers to managing noise well in a specific space and therefore acoustic performance defers from building's orientation, quality of materials used, workmanship and interior layout of the space. Acoustic measurements can be used for three different purposes, namely, to indicate the special effects of outside noise from adjacent working stations within the specific building, to indicate the ability of the working station in outdoor noise decrease and to indicate the effects of traffic noise on work perform (Wong & Jan, 2003). According to Krüger and Zannin (2004) not only noise levels but also the mean pressure noise levels should be measured in order to evaluate AP. Poor AP leads to stress, annoyance, communication problems and poor conversational habit (Wong and Jan (2003). Building's acoustic performance is affected by noise from vehicles and noise emit from other buildings in addition to their own internal noise. According to Oral, Yener and Bayazit (2004), AP of the building can be determined with the support of functional and performance criteria. To determine the annoying sound levels, various noise criteria have introduced such as noise criteria-NC, noise reduction-NR, perceived noise criteria-PNC and balanced noise criteria – NCB. These criteria are basically discussed about different noise curves which describe the background as a function of acoustic performance. These curves define the acceptable noise limits and frequency rages for different places by considering its' function and usage (Beranek, 1989; Demir, 2016).

When discuss about the limits of acceptability for acoustic performance, psychological necessities design to upkeep mental well-being and therefore there should not be unwanted noise that can affect building occupants. Working space needs to be silent which support for soothing and quite environment which is mainly absent in apparel buildings (Wessels & Basten, 2016). Ensure the physical health and safety of occupant is the aim of physiological requirements (Peters, 2013). Sociological requirements manage well-being of the community within which the occupants act. Further, the

requirement concerns about communication between individuals and other privacy requirements regarding to SP of the building (Peters, 2013). Economic requirements of SP aim to assign necessary properties in the most effective manner to fulfil occupants' requirements within the social context (Peters, 2013).

In textile or apparel factory environment, unwanted sounds can disturb workers from their functions and also it is a stress factor (Waldman & Spangler, 1989). Therefore, four guidelines are recommended to achieve better acoustic performance in the built environment, such as keeping out external noise, minimise internal sound, disturbance from building services and reduce vibration (Aronoff & Kaplan, 1995; Peters, 2013)

2.25 VP

According to standard EN 12665, VP is a subjective status of visual healthiness made by the visual environment. VP of a apparel building has a direct relationship between comfort as well as energy consumption of the building (Kruger & Zannin, 2004). VP is not that much standardised as TP since it depends on the daylight and other filters (Sicurella, Evola &Wurtz, 2012). Basic rules and guidelines for VP are established under EN Standard 12464-1 in terms of rules for artificial lighting in indoor working area by considering glare issues (The National Standards Authority of Ireland, 2011). Aim of VP should be considered the energy conservation as a real need, is to integrate artificial lighting and natural lighting in order to fulfil required lighting levels for the work tasks.

Distribution of light, illuminance and uniformity, glare, colour rending, colour of light, amount of daylight and flick are used to describe the VP (The National Standards Authority of Ireland, 2011). Illuminance measurements used to evaluate VP and different illuminance levels can be recognised for different tasks in apparel buildings and different functional areas of the building (Pheng Low et al., 2012). Glare can be identified as a common problem in visual performance. Especially fire damaged building is displayed as in black colour due to extensive smoke damage. Visibility also can be absent due to the damage of artificial lighting system of the building (Kinnear, 1986). According to the investigation done at secondary school in Singapore, artificial lighting performs a major role in VP. Findings revealed that it is unfeasible to switch-

off mechanical lighting at any point in time (Wong & Jan, 2003). EN Standard 15193 introduces an innovative approach to evaluate lighting controls logics for visual performance centred on the incorporation of daylight for cost saving purpose (The National Standards Authority of Ireland, 2011).

Daylight is a key consideration for visual performance these days and it is basically assessing through daylight factor (Sicurella, Evola and Wurtz, 2012). According to authors, considering only about the daylight factor is not sufficient to evaluate daylight availability for VP. Therefore, due consideration should be given to assess potential natural lighting and shading devices. To mitigate this issue and to provide better answer many studies are conducting regarding daylight autonomy, continuous daylight autonomy and useful daylight illuminance (Nabil & Mardaljevic, 2006; Reinhart, Mardaljevic & Roger, 2006; Reinhart & Walkenhorst, 2001; Roger, 2006).

2.25.1 Indicators for visual comfort from daylight

- **Frequency of visual comfort**

Frequency of visual comfort is defined as the percentage of time which acquire the appropriate values of daylight illuminance (Sicurella, Evola & Wurtz, 2012). Frequency of visual discomfort can be seen in above first and third situation due to insufficient and excessive daylight illuminance. Nabil and Mardaljevic have introduced the concept of useful daylight illuminance, which is similar to frequency of visual discomfort (Nabil & Mardaljevic, 2006).

- **Intensity of visual discomfort**

Intensity visual discomfort calculates based on spatial value, upper level of visual quality and daylight illuminance. When specifying optimum visual performance levels in working space, vital considerations need to be given to illumination level, luminance and colour rendering index (Noshuhaila, 2013; International Commission on Illumination, 2018). To obtain visual comfort, it is required to monitor and adjust the luminance and glare index values. Not only that, light reflection coefficients of different surfaces need to be evaluated because they act as a secondary light sources for visual performance of building.

2.26 Objective Measures for Building Performance Mandates

Table 7 presents the objective measures for all five BPMs.

Table 7: BPMs diagnostics measures

Performance mandate	Sub parameter	Unit	Instruments
SP	Distance	M or m^2	Measuring tape
TP	Temperature	^0C	Humidity and temperature meter
	Relative humidity	%	
	Average air movement	m/s	Anemometer
IAQP	Carbon dioxide level	ppm	Metrosonic indoor environment monitor
	Dust level	Mg/m^3	Grimm dust monitor
VP	Lighting level / illuminance	Lux	Lightmeter
AP	Ambient noise level	dBA	Sound level meter

Source: (Aji, Wang & Saltz, 2012; Dammerud, Barron & Kahle, 2011)

2.27 Acceptable Requirements of BPMs

Further, these performance mandates are affected with four limits of acceptability, namely

1. Physiological requirements
2. Psychological requirements
3. Sociological requirements
4. Economic requirements

Even though these four limits evaluate separately, these are interdependent (Kinnear, 1986). Physiological requirement of BPM deals with occupants' physical comfort, safety and health. It supports for basic bodily functions such as breathing, sight, hearing and movement from destruction such as fire, extreme temperature, poisonous fumes (Hartkopf et al., 1999). The psychological requirements of spatial performance address work and rest in order to influence to occupants' mental health. Sociological requirements or socio-cultural requirements consider well-being of the community and economic requirements seeks the best allocation of resources to fulfil user needs. Table 8 explain the summary of building performance mandates.

Table 8: Acceptable requirements of BPMs

Performance mandates	Physiological needs	Psychological needs	Sociological needs	Economic needs
SP	– Ergonomic comfort – No. of employees – Handicap access – Functional servicing – Building services requirements – Space need for employees – Space need for furniture – Space requirements for maintenance – Separation of work tasks into zones – Adequate safe for welfare facilities	– Privacy for occupants – Systematic arrangement of space – Habitability beauty, calm, excitement, view – Changeable spaces	– Interaction of occupants – Wayfinding – Functional adjacencies – Easy access to sky garden where could provide private space to conduct social activities	– Budget constraints – Conversion of materials and other resource – Cost – Space conservation – Energy targets – Quality consideration
TP	– Influences from air temperature, air velocity, radiant temperature & relative humidity – Uniformity of condition – Clothing – Metabolic heat – Wellbeing & sickness – Natural or mechanical ventilation – PPE	– Healthy plants. – Natural ventilation – Individual control.	– Flexibility to dress with the custom. – Others' contagion effects	– Energy conservation – Cost – Budget constraints – Occupancy load

IAQP	– Space planning according to nature of work regarding IAQ – PPE – Material selection & specifications – Building openings – Air purity	– Belief & imaginations	– Others' contagion effects	– Energy conservation – Cost
AP	– External noise minimisation – Internal noise minimisation – Vibration minimisation	– Quiet, Soothing	– Privacy and communication.	– Energy conservation – Cost – Material
VP	– Floor area – Appropriate lux levels – Building envelop and orientation – Design of openings – Occupancy factor – Task lighting	– Appropriate quantity of lighting. – Design of openings. – Low heat emitting lights/ cool white lights	– Sense of territory	– Cost – Energy conservation – Material and third party approvals

Source: (Hartkopf & Loftness, 1999; Kotzias & Pilidis, 2017; Ling-Chin et al., 2016; Papadopoulos; 2017; Markoska & Lazarova-Molnar, 2019)

It is essential to get a better understanding on past studies regarding BPMs. Table 9 describes the main stream literature about the building performance mandates

Table 9: Main stream literature about BPMs

Source	Study information	Data collection	Data analysis	Conclusion
Wong and Jan (2003)	Title: TBP evaluation of academic institution in Singapore Location: classrooms in a typical secondary school in Singapore	Instruments- interviews, surveys focused on users, questionnaire surveys, measuring tools, checklists, walkthrough, visual inspection by sensors, telemeters and data loggers.	Statistically analysed (correlation analyses, a regression model).	Block A Thermal performance is subjectively accepted but objectively failed Visual and spatial performance subjectively accepted Indoor air quality is subjectively failed and objectively accepted. Acoustic performance and building integrity subjectively as well as objectively failed. Block B Thermal, visual, spatial, acoustic and IAQ are subjectively accepted but thermal and acoustic are not within the recommended values.
Alm et al. (1999)	Title: The impact of human perception of simultaneous exposure to thermal load, low-frequency ventilation noise and indoor air pollution. Location: Climate chambers	Measurements	Logistic regression analysis	Impact to discomfort was analysed quantitatively
Astolfi and Pellerey (2008)	Title: Subjective and objective assessment of acoustical and	Measurements and questionnaire survey	Analysis of consistency: Normality test,	RII of environmental conditions on overall satisfaction with IEQ is not constant.

	overall environmentally friendly quality in secondary school classrooms Location: Secondary school in Italy		correlation: Pearson coefficient	
Choi, Aziz and Loftness (2009)	Title: Decision support for improving occupant environmental satisfaction in office buildings: The relationship between sub-set of IEQ satisfaction and overall environmental satisfaction. Location: Office buildings, USA	Questionnaire survey	T-test Coefficient	Females and males are slightly differently ranked of environmental conditions. Occupants working in the indoor areas ranked light quality higher than thermal quality.
Clausen et al. (1993)	Title: A comparative study of discomfort caused by indoor air pollution, thermal load and noise. Location: Climate chamber	Measurements	Probit analysis and linear regression analysis	Analysed the environmental conditions' changes on dissatisfaction.
Humphreys (2005)	Title: Quantifying occupant comfort: are combined indices of the indoor environment practicable? Location: Office buildings, European countries	Preference scales	Multiple regression analysis	Temperature and IAQ are the top two aspects which contribute to overall satisfaction.
Lai, Mui, Wong and Law (2009)	Title: An evaluation model for indoor environmental quality acceptance in residential buildings. Location: Residential apartments, Hong Kong	Participants judged the satisafaction with performance mandates	Regression analysis	Thermal and acoustic situations are strongly contributed to the overall satisfaction whereas IAQ has the lowest contribution to satisfaction.

Lai and Yik (2009)	Title: Perceived importance of the quality of the indoor environment in commercial buildings. Location: Commercial buildings, Hong Kong	Participants rated on thermal comfort, air cleanliness, odour and noise. And generate RII value.	Analytical hierarchy process	Occupants gender and their purpose of staying were affected by environmental conditions
Lai and Yik (2009)	Title: Perception of importance and performance of the indoor environmental quality of high-rise residential buildings. Location: Private and public high-rise residential buildings, Hong Kong	Participants rates	Analytical hierarchy process	Thermal quality has the highest priority among other mandates.
Wong, Mui and Hui (2008)	Title: A multivariate-logistic model for acceptance of indoor environmental quality in offices. Location: Air-conditioned office building, Hong Kong	Participants judgements with the dichotomous acceptability scales	X^2-test Regression analysis	TP was the main reason for occupants satisfaction

2.29 The Effect / Impact of Fire on BPMs

Fire is a hazard which is directly affected to the building operation and performance (Kodur, Kumar, & Rafi, 2019). The performance of the building measured under the sub categories such as SP, AP, VP, TP and IAQP (Oyedele, Tham, Fadeyi, & Jaiyeoba, 2012). The effect of the fire towards these six BPMs are described in Table 10.

Table 10: Effect of fire on BPMs

BPM	Effect/ Impact
SP	Spatial comfort is a perfect position between the human body's anthropometry and the behaviour adapted to spatial function (Ginting, Ginting, & Zahrah, 2018). When fire is occurred in the building, it produces extreme loads that often badly damage buildings and other structures. As a result, the space of the building may be damaged and it may disturb to the spatial comfort of the building (Osteraas, 2019).
AP	The acoustic comfort is the result of the ideal balance of acoustic conditions in an environment that should not be mystified with the complete absence of sound (International Acoustic Lab, 2008). Matos (2016) indicated that noise distractions triggered a 66% drop in concentration and performance. Further, the author explained that the acoustic comfort is very important to achieve the productivity of the organisation. In order to achieve the acoustic comfort, acoustical materials, which absorb sound in the environment can be used. When fire is occurred in the building, those acoustical materials may be damaged. As a result of absence of the acoustical materials the noise may be coming to the working environment in the factory. Then it disturbs the productivity and efficiency of the workers (GSA Public Buildings Service , 2011).
VP	Visual comfort is a subjective reaction to the amount and quality of light in a certain space at a given time (International Labour Organization, 2011). Specially, most of the activities in apparel sector are labour intensive and it is necessary to maintain an excellent work environment for maximizing productivity (Mohataz Hossain & Shabbir Ahmed, 2013). Smoke generated by the occurrence of the fire, affects to the visual comfort of the occupants

	(AirNow, 2017). Moreover, the flame and heat of the fire cause to visual discomfort.
TP	Thermal comfort is the condition of mind, which expresses satisfaction with the thermal environment (Olesen et al., 2001). The heat generated by the occurrence of fire caused to thermal discomfort. Thermal comfort is affected by heat gain and loss, metabolic rate, clothing insulation, air temperature, mean radiant temperature, air velocity and relative humidity (Health and Safety Executive, 2019). When fire occurred in the building, the heat gain is larger than the heat loss, air temperature is also increased.
IAQP	IAQP is the quality of the air particles in the environment (The National Institute for Occupational Safety and Health, 2013). When fire is occurred in the building, carbon dioxide is used to suppress the fire. As a result, the carbon dioxide particles in the environment are increased and it is affect to IEQ. Then, it may cause to happen headache and lung diseases.

However, the building performance evaluation has not yet become a mainstream or, indeed, a core activity in post-fire refurbished buildings (Sharpe, 2019). According to Garcia, Ahmed, and Mcgough (2017), it was difficult to carry out the building performance evaluation in refurbished buildings, especially in old buildings due to the lack of technical documents and non - documented retrofits regarding the building performance mandates. When renovating the fire damaged building, it is very hard to get back the property at its normal state (Wang, Wald, Torok, & Hajpal, 2008). Moreover, the authors explained that, post fire refurbishment projects had given attention to cover the damages which had not achieve the performance. Therefore, there is a lack of concern to evaluate the BPMs in post fire refurbishment also. Accordingly, vital importance is given to fire safety of a building structure. Henceforward, the refurbishment of fire damaged building is in the centre of interest nowadays (Maraveas, Fasoulakis and Tsavdaridis, 2017).

2.30 Summary

Durability or performance of the building is affected by numerous reasons and among that fire incidents may cause direct or indirect impacts to the present building or even in old age. Building collapses, implied damages and potential injury can be identified as main outcomes of fire incidents. Moreover, fire fatalities are reported frequently as a red light to the safety of buildings. Despite, many fire detection and protection techniques are available for buildings, building fires are still considered as a major threat to the occupants. Fire incidents have considerably increased during last years by endangering human lives and have caused economic and ecological damages. Shocking fire events challenged the essence of the building performance. On the other hand, facilitating comfort to the building occupants is the key essence of a building. Accordingly BPMs play a vital role in providing comfort to the building occupants. BPMs comprise of six aspects: SP, TP, IAQP, AP and VP. Building fire critically affect to the functionality of these BPMs. Further, among various reasons, uncontrolled fires, is one of the major reasons for building refurbishments as it causes building collapsing, the implied damage, potential injury and loss. Generally, soon after the fire, building condition assessment is performed. However, there are no evidence of any building condition assessment specially focusing to the performance mandates in post fire building refurbishment.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

Literature findings of chapter two are underpinned to the research area while chapter three exhibits to the reader about the research method followed. According to Mukherji and Albon (2018) research methodology is a process, which provides direction to the researcher to find answers to a problem. This chapter consists with research approach, research design and research techniques. Data collection and data analysis methods are elaborated under research techniques. Finally, the research process followed in the current study is showed.

3.2 Research Design

Research design is a systematic method, which transforms the research problem to the conclusion (Patten & Newhart, 2017). According to authors, research design provides logical assistance for every single step in the research. To attain the expected outcome, research design should properly design with high reliability (Ary, Jacobs, Irvine, & Walker, 2018). This research design comprise with a background study, a comprehensive literature synthesis, data collection through case studies, analysis of collected data, discussion, conclusion and recommendation.

3.3 Research Approach

Research approach provides a guide in organising research actions to fulfil the research aim (Rodgers & Yee, 2014). Rodgers and Yee further stated that, research approaches could be classified mainly into three approaches such as a qualitative approach, quantitative approach and mixed approach of both qualitative and quantitative approaches.

3.3.1 Quantitative Approach

According to the Appelbaum et al. (2018), quantitative approach is based on numerical values. This approach uses to generate statistical data and this quantitative approach, which is more objective in nature (Appelbaum et al., 2018). Results related to a sample population can be generated through the use of quantitative research approach

(Harwell, 2011). According to Creswell (2014), quantitative approach is utilised to prove the objectives through the development of relationships among the variable with use of statistical analysis. Moreover, Saunders et al. (2009) stated that, quantitative approach is engaged with statistics and numerical data.

3.3.2 Qualitative Approach

Qualitative approach can focus on a specific group of people and identify and it analyses their opinions, attitudes and views to find a solution (Symon, Cassell, & Johnson, 2016). Furthermore, qualitative approach is suitable in research where a small number of respondents are available and for emerging research topics through in-depth investigation (Yin, 2011). Further, when the research problem is a why, what and how type, qualitative approach is appropriate. Moreover to the author, a small sample of respondents is adequate when undertaking qualitative approach.

3.3.3 Mixed Approach

Mixed approach can be recognised as a dynamic method for expanding the scope of the study and improve the analytical power of the research (Sandelowski, 2000). Mixed approach is used to offset the limitations of other two approaches (Amaratunga, Baldry, Sarshar, & Newton, 2002). Under the mixed method approach researcher can gain detailed understanding about the research problem. Moreover, using mixed method approach improve the rationality and trustworthiness of the data and strengthens implications by facilitating various opportunities to observe data (Abowitz & Toole, 2009).

3.3.4 Selected Approach for the Study

This research was conducted to enhance building performance of fire damage refurbished buildings in apparel manufacturing sector in Sri Lanka. To achieve that, the researcher has to evaluate human opinions and perceptions and also need to gather accurate data about fire risk, refurbishment practices and building performance of apparel buildings. To gain knowledge about fire safety management, refurbishment practices and measures in enhancing BPMs, an in-depth analysis was required to be carried out. In addition, to evaluate the relevant factors contribute for fire incidents in apparel buildings in Sri Lanka, an in-depth analysis was not required. Nauom (2007)

stated that where in-depth analysis is not required, quantitative analysis can be adopted. Therefore to identify and rank factors contribute for fire incidents, a quantitative analysis was adopted. Accordingly, a mixed approach was undertaken for this research where considering data collection method and type of the research (Kumara, 2011). Moreover, Fellows and Liu (2015) stated that a mixed approach is the best approach to gaining a multi - dimensional view of the research area and to validate both external and internal attributes.

3.3.5 Strategies of Mixed Approach

The research strategy assists specific direction for process and procedures in a research design (Creswell, 2013). Under mixed approach, Creswell (2014) mentioned six strategies as sequential explanatory, sequential exploratory, sequential transformative, concurrent triangulation, concurrent nested and concurrent transformative. First, sequential explanatory strategy involves collection and analysis of quantitative data followed by the qualitative data collection and analysis. Equal priority is given to the two phases in the sequential explanatory strategy. Second, sequential exploratory strategy is somewhat opposite of sequential explanatory method, which facilitates the collection and analysis of qualitative data followed by quantitative data collection and analysis. In here also, equal priority is given to two phases but priority can be given to either. Third, sequential transformative strategy involves two distinct data collection phases and either type can be collected first. Fourth, concurrent triangulation strategy has two concurrent data collection phases. Fifth, concurrent nested strategy involves two data collection methods, data are mixed during analysis phases. Last, concurrent transformative strategy is guided by a specific theoretical perspective.

3.3.6 Selected Strategy of Mixed Approach for the Study

In this study, concurrent nested mixed method was involved in order to achieve the aim of this research. In this strategy, priority was given to the qualitative data collection with less emphasis placed on quantitative data collection approach. Purpose of involving this strategy was to address different research objectives and garner information from different groups and levels within the cases.

3.4 Research Methods

According to Saunders, Lewis and Thornhill (2009), survey, experiment, case study, grounded theory, ethnography, action research and archival research were recognised as research methods. As this research was intended to evaluate building performance of post-fire refurbished buildings in apparel manufacturing sector, case study technique was involved for the study.

3.4.1 Case Study

Creswell (2013) stated that case study involves to investigate a particular contemporary phenomenon within its real life context using multiple sources of evidences. By involving case study, researcher can gain a rich understanding of context of the research (Yin, 2009). Case studies can be conducted as single case study or as multiple case studies (Yin, 2009). For rare and unique incidents, single case study can be adopted whereas, multiple case studies are used when similar or contrasting results due to predictable reasons are generated. In this study, multiple case study method was involved to carry out the research as it enhance the research findings and generated results were not unique to a particular case.

Further, multiple case studies can be divided into two methods, namely; multiple holistic and multiple embedded (Yin, 2003). In the holistic method, case is the unit of analysis and there are several units of analysing the embedded method. Accordingly, this study was focused on multiple holistic method.

Random selection strategy and information-oriented selection strategy are the main two methods for the selection of cases (National Academies of Science, Engineering, and Medicine, 2009). In random selection method, cases are randomly selected from a large sample and information-oriented selection, cases are selected to illustrate a characteristics or attributes of interest. In order to accomplish the research aim, this study involve information-oriented selection as the strategy for case selection. In information-oriented selection, following specific criteria were applied for selection process.

- Selected case should be a refurbished building due to fire incident
- Selected case should be in apparel manufacturing sector
- Selected case should have more than 1000 employees
- Selected case should facilitate to conduct interviews and questionnaire survey
- Selected case should provide relevant information to the researcher

Accordingly, three cases were selected by considering above five selection criteria.

Case boundary and Unit of analysis

In order to determine the unit of analysis, it is suggested to focus on the area required to be analysed. (Baxter & Jack, 2008). This study focus on building performance of fire damaged buildings in apparel sector. Therefore, the unit of analysis is 'building performance of post-fire refurbished apparel buildings' and case boundary is 'post-fire refurbished apparel buildings in Sri Lanka'.

3.5 Research Techniques for Data collection

Data collection method should be carefully chosen based on its rationality, appropriateness, validity and amount of data needed (Polonsky & Waller, 2011). Accordingly, literature review was conducted as secondary data collection and primary data collection supported by interviews and questionnaire for the research.

3.5.1. Interviews

Interviews was conducted among eighteen (18) professionals under three main groups: professional in fire safety management, professional in refurbishment projects and professionals in BPMs (six professionals for each group). Accordingly, three different interview guidelines were prepared. More detailed qualitative information were aimed to gathered through interviews.

- **Professionals in fire safety management**

Selected six professionals who have direct influence and relationship with fire safety management systems in three cases. Two professionals from each case were selected to gather data for the study. Purpose of selecting these respondent group is to get

information and opinions in fire safety management practices in three cases. Annexure I presents the interview guideline for professionals in fire safety management.

- **Professionals in refurbishment projects**

Selected six professionals who have competent knowledge in past refurbishment projects. Two professionals from each case were selected to gather data for the study. Purpose of selecting these respondent group is to get information and opinions in fire damage refurbishment activities in three cases. Annexure II presents the interview guideline for professionals in fire safety management.

- **Professionals in BPMs**

To gather information about practices of BPMs in three cases, six professionals were selected. Same as other respondent selection, two professionals from each case were selected to gather data for the study. Annexure III presents the interview guideline for professionals in BPMs.

3.5.2 Questionnaire survey

Questionnaire survey was used to gather data from 36 professionals who have the sufficient knowledge and experience about past fire incidents in three cases to identify the most relevant factor contribute to building fire incidents in apparel sector. Total of, 54 questionnaires were distributed and among that 36 respondents answered the questions, recording a response rate as 66.6%. Factors identified from literature review were ranked using 5 point Likert scale. Annexure IV presents questionnaire survey guideline.

3.6 Sampling Techniques

Sampling technique can be selected by considering the research question and the type of data aiming to analyse (Rowley, 2014). As this study focus on the building performance of fire damaged apparel buildings, sample should comprise with respondents who are knowledgeable and experienced regarding the research area. Non-probability sampling was selected since there is no probability attached to the unit of the population and selection relies on the judgement of researcher (Rowley, 2014). Purposive sampling technique as a non-probability sampling technique was used as

the most suitable sampling technique for interviewees. Further, Heterogeneous sampling as a type of purposive sampling technique was selected, because this study involves three sub groups of interviewees. Convenient sampling technique for respondents in questionnaire survey was selected for this research (Rowley, 2014). According to Tongco (2007), selecting respondents in purposive sampling technique is based on researcher judgment. Further, convenient sampling selected based on respondents availability and willingness to take part in the data collection (Punch, 2006).

3.7 Data analysis

Collected data is analysed by using qualitative analysis tools and quantitative analysis tools.

3.7.1 Qualitative data analysis

Data analysis involved in evaluating data gathered from literature review and data collection stage to generate useful information (Kline, 2004). Content analysis in manual is used as a qualitative data analysis technique to illustrate and analysis qualitative data gathered through interviews (Renz, Carrington and Badger, 2018).

3.7.2 Quantitative data analysis

Quantitative data gathered from questionnaire survey was analysed using RII. Respondents of questionnaire survey were asked to mark the importance of each aspect by prioritising the factors which contribute to fire incidents in apparel buildings. RII was used as the analysis technique for quantitative data. Sambasiva and Soon (2007) mentioned that RII can used to rank attributes. Results obtain from 5 point Likert scale were transformed to identified priorities with RII (Rooshdi et al., 2018). RII was calculated using following equation:

$$RII = \frac{\sum w}{AxN}$$

Equation 1: RII

Where, W = Weighting given for each factor by respondents

A = Highest weight in the scale

N = Total number of respondents

3.8 Research Process

The research process shows a step by step guideline, which include formulating the research problem, outlining aim and objectives, exploring literature, research method, data collection and analysis (Jonas, 2017). Research process provides a basic map to monitor the research progress (Polonsky & Waller, 2011). Figure 11 demonstrates the research process of the study.

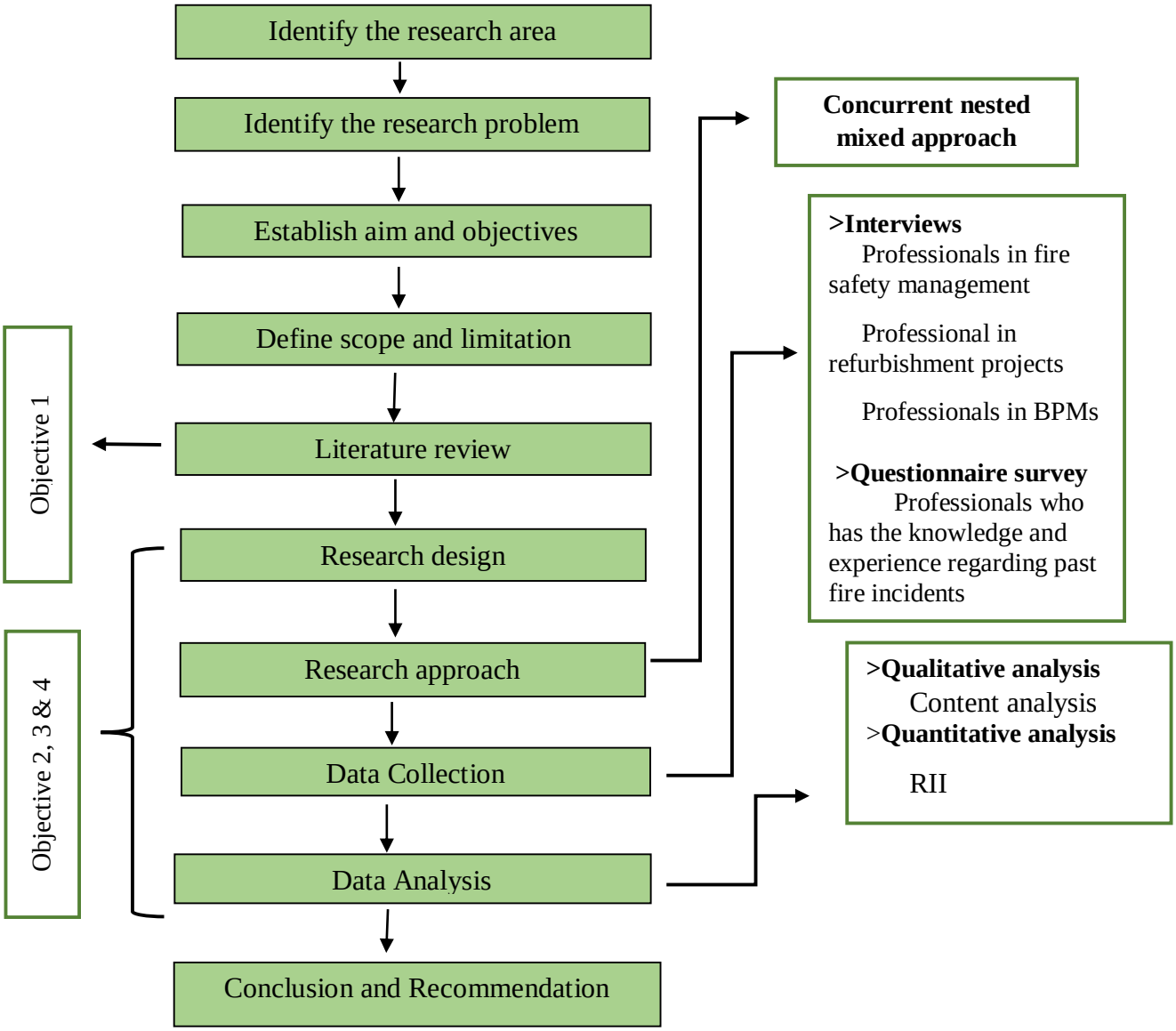

Figure 11: Research process

3.9 Chapter Summary

This chapter illustrates the research process and methodology which was used in this research with justifications. The research methodology chapter presents about research design, research approach and research process which was involved throughout the whole research journey. A concurrent nested mixed approach was used as the research approach for the study. Semi-structured interviews and questionnaire survey were used to collect data. Collected data were analysed by content analysis as qualitative analysis tool and RII as quantitative analysis tool.

CHAPTER 04

4.0 DATA ANALYSIS, RESEARCH FINDINGS AND DISCUSSION

4.1 Introduction

The chapter three of the study present the research methodology while laying outline to successfully addressing the research gap. The chapter four presents data analysis achieved through data collections by means of semi structured interviews. Interviews were conducted among three different groups in three apparel buildings that are refurbished after fire incidents. Objective of chapter four is to express the knowledge on data gathered and their implication after a systematic analysis of data. Discussion on data collection and analysis extends to major three areas. Initially, fire risk and fire safety condition in apparel buildings were identified. Then, study was focused on refurbishment projects due to fire incidents in apparel buildings. Finally, building performance of refurbished apparel buildings were evaluated under five BPMs.

4.2 Data Collection

4.2.1 Semi Structured Interviews

Data for the analysis were captured by semi structured interviews. Semi structured interviews were used to gather data from eighteen (18) respondents under three (3) main categories. Accordingly, separate three interview guidelines were prepared to evaluate opinions of experts in fire safety management, building refurbishment and BPMs. Detailed descriptions of interview guidelines present in Table 11.

4.2.2 The Profile of the Case Study Projects and Respondents

Data collected from the above means were used to develop a profile of the projects and the respondents. Table 12 presents the profile of the selected cases.

Table 11: Summary of interview guideline structure

Interview Guideline	Respondent Category	Main Section					
		01	**02**	**03**	**04**	**05**	**06**
A	Experts in fire safety management	Details of respondent	Fire safety management	Factors contribute to building fire incidents	Details of the past fire event	Challenges in fire safety management system	-
B	Experts in refurbishment projects	Details of respondent	Building refurbishment	Details of fire refurbishment project	Challenges in refurbishment project	-	-
C	Experts in BPMs	Details of respondent	Spatial performance	Thermal performance	Indoor air quality performance	Visual performance	Acoustic performance

Table 12: Profile of selected cases

Case	Description	Business scope
Case A	Number of workers: 2 600 Location: Kurunegala	Products range: Men's & Boys' Underwear, Briefs and Vests, Women's or girls' undergarment, stockings, hosiery, nightdresses, pyjamas, bathrobes, dressing gowns and similar articles. Accessories such as hooks and eyes, tubes, under-wires, bra cups and laminated foams
Case B	Number of worker: 2 300 Location: Gampaha	Products range: casual wear, intimate wear, sleep and loungewear and active wear. Service range: apparel supply chain, and product development and innovation
Case C	Number of worker: 1800 Location: Gampaha	Products range: dress shirts, knit shirts, casual pants and blouses

The respondents were selected while considering their expertise on fire safety management system, building refurbishment and BPMs. Table 13 presents summary of selected respondents from each category in three cases for the interviews.

Table 13: Summary of interview respondents

No	Case	Category	Respondent Code	Designation	Years of Experience
1	Case A	Experts in fire safety management system	AF1	Head of Compliance	15
2			AF2	Assistant Manager – Environment, Safety and Health Management System	8
3		Experts in refurbishment projects	AR1	Engineer – Civil	7
4			AR2	Project Manager	9
5		Experts in BPMs	AB1	Deputy General Manager	17
6			AB2	Facility Executive	8
7	Case B	Experts in fire safety management	BF1	Assistant Manager – Occupational Health and Safety	8
8			BF2	Executive Occupational Health and Safety	6
9		Experts in refurbishment project	BR1	Plant Engineer	13
10			BR2	Senior Engineer – Civil	12
11		Experts in BPMs	BB1	Senior Executive – Facility Planning	8
12			BB2	Executive – Energy Management and Sustainability	9
13	Case C	Experts in fire safety management	CF1	Compliance auditor	8
14			CF2	Executive Compliance & Operation	6
15		Experts in refurbishment project	CR1	Project Manager	13
16			CR2	Architect	6
17		Experts in BPMs	CB1	Director	19
18			CB2	Assistant Manager – Group Sustainability	11

4.2.3 Work Experience of Respondents

All eighteen (18) respondents present more than five years of experience. Further, 61% of the respondents were in between 5 to 10 years of experience, 22% of respondents were represented 10-15 years group and 17% of the respondents were in between 15-20 years of experience. Accordingly, these experience level can be considered as excellent and it drive to gain more validate date. Graphical representation of respondents' years of experience is shown in Figure 12.

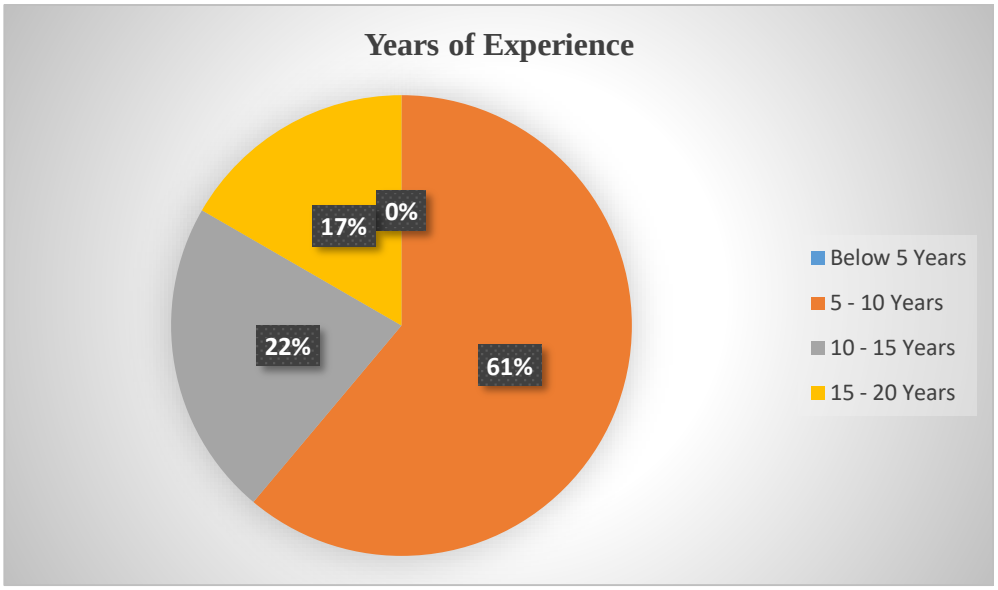

Figure 12: Work experiences

4.3 Analysis of the Findings

4.3.1 Challenge of fire resistant buildings

Professionals of fire safety management system in each case were used to evaluate their views and reasons for considering fire resistant building is still a major challenge worldwide. All six respondents from three cases answered for the question and all of them agreed that there is a major challenge in achieving fire resistance in buildings. The specific reasons, which consider fire resistant building as a challenge analysed and presented in Table 14.

Table 14: Reasons to considering fire resistant building as a major challenge

Reasons	**Respondent code**					
	AF1	AF2	BF1	BF2	CF1	CF2
Technical gaps and errors	✓					
Human errors	✓	✓		✓		
Not following specific standards and guidelines		✓			✓	
Budget constraints		✓		✓	✓	✓
Lack of maintenance			✓			
Errors in fire assessments			✓			
Failures in fire audits			✓			
Lack of consideration in passive fire protection system						✓
Low consideration about fire safety at the initial stage of the design						✓

Fire resistant building is a major challenge worldwide as per the opinions of the respondents. The top most reason to consider fire resistant building as a challenge is budget constraints. Respondent AF1 explained; "*I think, fire resistant building is still a major challenge because it is a very costly investment. Therefore, people take minimum precautions to protect their buildings from fire with small budget".* Moreover, respondent AF2 elaborated; *"Fire resistant building is not an impossible task if we have willingness and ability to accomplish that. Willingness means we should have good fire safety practices by following specific standards and guidelines and also ability in purchasing fire resistive tools and equipment without considering cost factor. As an example, it is very costly to use fire resistive cables for the whole building. Therefore people use fire resistive cables only for fire system. But if we can*

purchase and use these cables for the whole building, fire risk can be mitigated to a greater extend."

Moreover, reluctant to follow specific standards and guidelines, and human errors are also identified as top most reasons. Respondent BF2 explained; *"Even though the building itself or the materials that are used to build the building are fire resistant, if the processes that is practiced in the particular building are not properly followed by the employees, then there is still possibility for high fire risk".* Especially, respondent BF1 pointed out errors in risk assessments as another reason and detailed explanation as; *"Errors in risk assessments can also be identified as a reason. Risk assessment is the overall procedure of hazard identification, risk analysis, and risk evaluation. Specially, this risk identification process needs to be repeated according to new changes in the building. But, updating the list of hazards is not conduct properly and that led to create failures in the fire safety system".* Requirements in both active and passive fire protection need to be fulfilled to make a building fire resistant. According to respondent CF2, *"Passive fire protection acts as a hidden system but major role in building fire safety which is considered as the integral component of the elements of building structural fire protection system. This passive fire protection system attempts to slow the fire spread by means of fire resistant doors, walls and floor. But, building owners are very much focused on active fire protection than the passive fire protection which may lead to major damages in fire incident".*

Accordingly, due to numerous reasons fire resistant building is still a major challenge worldwide even though building experts have taken enormous decisions and involved advanced techniques to construct and to maintain buildings.

4.3.2 Fire Risk in Apparel Manufacturing Sector in Sri Lanka

From the views of all the respondents, it was evident that there is a fire risk in apparel sector Sri Lanka. Five respondents out of six, stated that, high fire risk can be recognised in apparel sector Sri Lanka (83.4%) and one respondent stated that, there is a moderate fire risk in apparel sector (16.6%).

Respondent CF2 explained; "*Fire risk in apparel sector is high due to the nature of the business. In an apparel factory high fabric storage can identify because of process*

flow chart is fully relates with fabric materials". 'Chemical usage' recognised as an attribute which affect fire risk in apparel sector by BF2. Moreover, CF1 explained when flammable substances are used for preparation of emulsion thickening in pigment printing and then printed clothes which bake at high temperature can cause significant fire risk.

Usage of machineries and equipment also identified as attributes which cause for fire risk in apparel sector Sri Lanka. Respondent BF1 and AF2 explained involvement of large number of sewing machines and other production related machineries, boilers, generators, steam irons etc. can also contribute to fire risk. This factor further emphasised by Respondent BF2 as; *"Not only general machineries and equipment but also high heat generating machines such as thermal printing machines, boilers, heat sealers, high temperature dyeing machines and iron machines are highly influenced the fire risk".*

Respondent CF1 elaborated that 'Frequent staff turnovers' as another factor which indirectly affect fire risk in apparel sector Sri Lanka. Further the respondent explained that majority of employees in production are early school leavers and most of them are from different cultural backgrounds with low educational knowledge. They frequently change their job and due to this, having experienced and trained employees for fire safety is difficult.

On the other hand, respondent BF2 stated there is a moderate fire risk in apparel sector Sri Lanka. Further, respondent BF2 asserted; *"Apparel sector of Sri Lanka is not an energy intensive sector rather it is human intensive sector. There are large number of machineries in apparel sector but most of them are only low voltage equipment when compare with other industries. But, large workforce can be seen in apparel sector Sri Lanka and it is nearly 990,000 employees. Therefore, having large low voltage machines and large workforce creates low probability and high impact respectively. Consequently, moderate fire risk can be identified in apparel sector Sri Lanka".*

4.3.3 Fire Safety Systems in the Organisations

Case A, B and C have used various elements and equipment for fire detection, notification and suppression. Respondent AF1 explained that; "*There should be a good*

symbiosis between elements of fire detection, notification and suppression to effectively fight for building fires". Smoke detectors, heat detectors, pull stations and beam detectors have installed as elements in detection system in case A. Respondent AF2 stated*; "In our building, beam detectors use for production floor because the roof height of that area is comparatively high and due to that, use normal smoke detectors for such height is not practical".*

Respondent BF1 explained the importance of alarms and notification systems as*; "Fire notification systems are a compulsory requirement in any facility which alarms that notify employees and emergency public respondents such as police and fire brigade".* Further, AF2 highlighted that "*Even though the technology in fire notification systems is advance to automatically close the fire doors and notify relevant public emergency respondents, but in our fire notification system, we do not have such advanced features".* Fire alarm control panel, primary power supply, secondary power supply, fire alarm notification appliances such as horns, sirens, bells, speakers identified by Respondent BF2 as elements for fire notification system. Especially, all three cases have installed addressable fire alarm systems, which are connected to central control panel and enabling the exact detector that was triggered.

Fire protection system include fire exit system, fire alarm system and fire suppression system. All three cases have involved active fire protection and passive fire protection measure to their buildings but they have given more consideration to active system than passive measures. Respondent CF1 explained that they use fire resistive doors and floor - paints for boiler and generator rooms. Additionally, CF2 explained active fire protection measures as; *"Measures that direct physical actions to reduce the growth or spread of fire".* All three cases have sprinkler system, extinguishers, hose reels fire hydrant system as their active fire-fighting measures.

4.3.4 Advance Early Fire Detection Techniques

All three cases practice only risk assessment and thermography testing as their early fire detection techniques. All six respondents stated that they conduct thermography survey not related to fire system maintenance but under annual electrical panel testing. Respondent BF2 explained; *"Thermography survey is very important because it*

involves latest infrared thermography testing equipment to capture hot spots which have potential fire hazards".

According to Respondent CF1 view, normal wear, corrosion, vibration, expansion and contraction, chemical reactions, temperature changes may lower the conductivity which then increase resistant. This incensement in resistant leads to increase temperatures of electrical components. Further, Respondent CF1 explained; *"This temperature elevation often cannot be identified by naked eye therefore by using IR camera we can measure and indicate potential trouble spots".*

Preventing electrical failures and unexpected downtimes can be recognised as benefits of conducting thermography survey by Respondent BF1. Apart from that Respondent BF2 stated *"Thermography survey is not a high costly task but it is cheaper to make any maintenance or repairs before they reach the point of no return".*

4.3.5 Fire Safety Teams in the Organisations

All three cases have fire safety teams for their organisations but the composition is slightly difference to each other. Every employee get fire evacuation training at their induction programmes but fire-fighting and fire rescue trainings are given to selected employees. Respondent AF1 described about their fire team as; *"We have two separate teams for fire-fighting and fire rescue. Rescue team mainly responsible for life safety and fire-fighting team prevents the spread of and extinguish fires. At least one person from each department and considerable about of staff in production represent fire rescue team. On the other hand, two persons from each department and considerable about of staff in production represent fire-fighting team. There are around 150 employees in both teams".*

Case B has around 280 employees in their fire safety team and both case A and B are conducted training sessions for their teams once in every six months. Respondent BF2 elaborated; *"We are supposed to train 10% of carder for fire safety. Therefore, organisation conduct fire safety training with the help of fire brigade and it is a half day training programme in every six months. On the other hand, we do a fire drill covering all the employees in the factory in every six months. Moreover, we have emergency rescue team not only for fire but also all emergency situations. This*

emergency rescue team is headed by plant general manager and he is the emergency commander, further there are deputy emergency commander, emergency communicator, emergency controller, fire team and nurse".

Respondent CF2 emphasised *"General requirement is to have 10% trained staff for fire-fighting from overall carder, but here we have 40% trained staff for fire-fighting. Organisation provides separate uniforms to these fire-fighting staff named as 'fire squad' in their uniforms for easy recognition. Physical fitness of these firefighting staff is checked annually*" as a best practice when compare with other two cases. In addition to this practice, case C pay special attention to "special worker" category and assign a buddy person for each worker in special category to support in an emergency situation. Provide separate uniforms for special worker category for easy identification.

4.3.6 Regulations and Guidelines Related to Fire Safety in Apparel Sector

From the views of all the respondents, it was evident that there is inadequacy of detailed fire regulation specifically for apparel sector in Sri Lanka. Nonetheless, this inadequacy of specific legal requirements are fulfilled by various customers' (buyers') requirements and they play a dominant role in every apparel building.

All three cases follow Factories Ordinance to safe guard their building fire safety system. Respondent AF1 explained; *"We mainly follow eight subtitles in Factories Ordinance to ensure building fire safety; namely, means of escape in case of fire, regulations as to means of escape in case of fire, safety provisions in case of fire, instructions as to use of means of escape in case of fire, regulations requiring the installation of fire-fighting appliance, underground rooms, power to extend dangerous occurrences provisions as to notice the accidents and general register"*. Accordingly, every factory need to be inspected and certified their means of escape by the relevant District Factory Inspection Engineer and the certificate should attach in the factory's general register. Further, Respondent AF1 highlighted; *"If the certificate not obtained for relevant premises, we have to pay around twenty five thousand rupees as penalty and also five hundred rupees per day for not correcting the fault and continue the operation".*

In addition to above requirements, Respondent CF2 explained; any doors opening to corridors or staircases in more than ten people employed room should open to outward or be constructed as a sliding door and every lift and access path to those lifts inside the factory should be constructed as fire resistant. Further, Respondent CF2 stated; *"We have audio system which is audible throughout the factory for giving warnings in case of fire as a requirement in Factories Ordinance that applicable for a factory more than twenty people employed or high flammable materials stored".* Respondent BF2 emphasised that the Factories Ordinance (No. 15 of 1942) is highly outdated and its new amendment which is No. 19 of 2002 should be modified since it is also prepared 18 years back.

Moreover, Respondent BF1 pointed out that CIDA Fire Regulations can be used since it has new and detailed explanations for fire safety system namely; smoke fire lobby, structural fire precautions, fire detection and alarm systems, fire extinguishing appliances, special use, occupancies and structures, accessibility for fire-fighting, inspection maintenance and testing, and service contract regulations. Respondent BF2 opined that Factories Ordinance is not given any facts about the firemen's lift but in CIDA fire regulation has detailed explanation for that. Respondent BF1 stated that; *"Firemen's lift in the factory should has 1000 kg rated load and the lift should be reached to the top floor within 60 seconds according to the CIDA regulations".* Respondent CF1 explained that fire pumps should certify by independent testing authority and pumps should operate automatically in the start and manually stopped at the end. Further, Respondent CF1 affirmed; *"An audible and visual alarm systems should be installed in the control room to indicate fire pumps have started".*

Respondent CF2 explained that Board of Investment of Sri Lanka (BOI) has implemented General Guidelines for Factory Buildings and according to that 20 feet fire gap should be maintained from the factory's boundary wall to control the spread of fire to adjacent buildings. Apart from that, required precautions should take under experts' advice for places where explosive substances involved in the process. Besides, Occupational Health and Safety Assessment Series (OSHAS) is provided further information which can apply for apparel sector. Emergency action plan and fire prevention plan are need to be prepared according to OSHAS as per Respondent CF2

view. Respondent AF2 stated; "There are around 50 codes in NFPA guidelines but we mainly refer to standards for; portable fire extinguishers, Co2 extinguishing system, fire alarm and signalling, fire doors and other opening protectives and codes for means of egress".

Apart from all these regulations and guidelines, all three cases follow their customers' requirements regarding fire safety. Case A primarily follow "The Walt Disney Company-International Labour Standards" and Respondent AF1 explained; *"We have to follow Disney Company standards as they are the main customer in our organisation and in the standard ask to maintain documents regarding fire drills, fire inspection reports, fire prevention certificates and emergency evacuation plan".* Respondent BF2 emphasised; NIKE guidelines for occupational health and safety is one of the requirement that apply from customer side to ensure building fire safety in Case C. Respondent CF2 explained; *"Adequate fire exits, alarms, fire protection systems, structural protection should maintain according to Calvin Klein's guidelines as a customer's requirement".* Further, Respondent CF2 explained one of their customer requirements as; *"According to NIKE requirements we should create and maintain 'culture of safety' and should improve fire safety knowledge according to their procedure which is designed with a collaboration with Fair Labour Association and Institute of Occupational Safety and Health".*

4.3.7 Factors Contribute to Fire Incidents in Apparel Buildings

Twenty three (23) factors recognised through the literature review and then those factors questioned to recognise the suitability to apparel sector Sri Lankan context. Likert scale of 1 to 5 used to assess their opinion. All respondents answered to this question based on their opinion and experience. All responses evaluated and ranked using RII values as shown in the Table 15.

Table 15: Ranked factors based on RII value

Factor	RII Value	Rank
Faulty wiring	1	1
Welding work with electrical sparks	0.9888	2
Accumulation of waste fabric materials, garbage and papers	0.9666	3
Locations of firefighting services in Sri Lanka	0.9555	4

Building design features/ materials which contributed to the fire development and fire spread	0.9444	5
Lack of quick response of fire brigade	0.9222	6
Careless smoking (construction workers are flipped away their cigarette while there are working)	0.9111	7
Sloppy maintenance on electrical tools	0.9	8
Errors in fire detection system	0.8888	9
Errors in fire protection system	0.8777	10
Architects' low considerations in fire safety	0.8666	11
Improper identification of fire exits, fire doors, fireman's elevator	0.8444	12
Integration errors of building design/ architectural features and fire safety system	0.8333	13
Lack of usage in fire resistant materials	0.8222	14
Large number of horizontal/ vertical continuous openings	0.8	15
Building designing errors	0.7888	16
Not involving the building for its' original design function	0.7666	17
Differences between considerations in policies and findings of actual fire incidents	0.7555	18
Poor equipped fire brigade	0.7444	19
Lack of staff in firefighting service organizations	0.7333	20
Fire risk in HVAC system	0.7111	21
Wooded building structures	0.7	22
Lift shafts which its doors removed or opened due to refurbishment	0.6777	23

Table 15 shows that 'faulty wiring' was ranked with the highest relevance (RII value of 1) followed by 'welding work with electrical sparks' with RII value of 0.9889 and 'accumulation of waste fabric materials, garbage, paper' was ranked third with RII value of 0.9667. 'Locations of fire-fighting services in Sri Lanka' and 'Building design features/ materials which contributed to the speed fire development and fire spread' are ranked as fourth and fifth relevant factors.

On the other hand, 'lift shafts which its doors removed or opened due to refurbishment', 'wooded building structures', 'HVAC system', 'Lack of staff in fire bridges' and 'poor equipped fire brigade' were ranked least with RII values of 0.6778, 0.7, 0.7111, 0.7333 and 0.7444, respectively. These facts reveals that least ranked factors are comparatively less contribute to fire incidents in apparel sector Sri Lanka.

Faulty wiring has the highest RII value and especially it was weighted as five by all respondents. Further, this can be buttressed with the Respondent AF2, CR1 and BB1 facts. Respondents AF2 stated that *"Faulty or outdated wiring frequently cause for fire incidents in apparel building and also wiring capacity may not be capable enough to support new and changed electrical systems in the building".* Moreover, Respondent CR1 highlighted that *"As electrical system of the building get older, the wiring also wears and wires are strung about that loosen eventually and could possibly breakdown and cause a fire".* Respondent BB1 suggested that; *"We can easily identify heat up and faulty wiring that can easily catches fire by paying attention to flickering lights, excessively hot electrical appliances, sparks from appliances and unexplained burning smells".* Similarly, Respondent AB1 explained that hot slag, torch flames and sparks are caused for welding fires which is nearly 2000 degree Fahrenheit hot and can travel up to 10 meters horizontally when falling. Important facts recognised regarding 'accumulation of waste fabric material, garbage and paper waste' factor and it is explained as; *"Nearly all materials in apparel sector being used are flammable to some degree and specially low density fibres such as fabric off-cuts or open layers of wadding can burn very easily"* by Respondent CF2. Further, Respondent AB2 explained that waste yard should be separated according to contaminated waste and non-contaminated waste.

'Lift shafts which its doors removed or opened due to refurbishment', 'wooded building structures' and 'HVAC system' can identified as least factors that contribute for apparel fire incidents. Supporting this results, Respondent CR2 revealed that *"Opened or removed doors in lift shafts are very uncommon situations when compare with other factors*". Moreover. Respondent AB1 explained that wooded buildings are not usually involved for apparel building instead of architectural design feature. Even though the spread of fire in a wooded building is high, its possibility to occur a fire is comparatively less in Sri Lankan apparel sector because use of less use of wooded elements in Sri Lankan apparel buildings. 'HVAC system' also in low ranked position since most of HVAC systems has inbuilt fire safety precautions such as fire dampers closed and smoke detectors in duct system.

In addition to those found from literature, twenty-six (26) factors which contribute to fire incidents were newly recognised through interviews and questionnaire survey. 'Worn out electrical sockets and grounding issues' and 'high cost in installation and repairs of fire system' identified by Respondent AF1 and CF2 recognised 'improper chemical storages' as another factor which contribute for fire incidents in apparel sector. *"Even though the fire safety system test and monitor properly, there is still a chance for 'sudden breakdowns' which lead to increase severity in fire incidents"* as explained by Respondent BB2. "Apart from that, 'penetration through fire rated barriers' pointed out by Respondent BF2 and respondent of questionnaire survey. Respondent AF2 and respondents of questionnaire survey stated that, 'deficiencies of commanding at fire scene', 'lack of fire training and awareness', 'lack of technical knowledge regarding fire safety', 'lack of professionalism in fire service providers', 'inadequacy of fire service providers in Sri Lanka', and 'lack of competent and educated fire protection engineers in Sri Lanka' as contributing factors for fire incidents. And also, 'start fire safety practices in the middle of the business operation', and 'lack of safety culture and safety attitudes in Sri Lanka' emphasised by Respondent AR2.

Respondent AB1 emphasised that "*High turnover in apparel staff can be seen due to nature of the business and cultural differences of employees, and this can result in low trained employees regarding fire safety, not having well-experienced staff to fight against fire and having lack of awareness regarding fire evacuation and fire-fighting"*. 'High heat generating machines' such as heat seal machines, boilers, thermal printing machines, high heat dyeing machines recognised by Respondent BF1. Further, 'Not adhere to standard operation procedures (SOP)', 'less focus on passive fire protection', and 'placement issues of several operational functions' such as chemical storage placed near to waste yard and chemical storage near to kitchen or smoking area emphasised as factors by Respondent BF2. Respondent CB1 explained; *"lack of interest and involvement in fire drills and fire training, and difficulties in implementing fire related regulations or guidelines also can be identified as factors that trigger the fire incidents".* Further, Respondent CB1 clarified that due to the lack of interest and

knowledge on fire trainings, department heads tend to recruit lowest productive employees in their departments for fire training.

Apart from all these factors, loopholes in regulations and guidelines regarding fire safety also highlighted by many respondents. Respondent CF1, CF2 and respondents of questionnaire survey identified ‘lack of specific fire regulations for apparel sector Sri Lanka’, and also CF2 recognised ‘less regulations regarding passive fire protection in apparel sector’, and ‘interpretation differences in various fire regulations, standards and guidelines’. Furthermore, Respondent BF2 pointed out; ‘inadequacy of proper monitoring mechanism for fire regulations and guidelines in Sri Lanka’, ‘vague definitions in fire regulations’, and ‘outdated factories ordinance’ as issues in regulatory framework which related to fire safety in apparel sector Sri Lanka.

Accordingly, altogether forty-nine (49) factors which contribute to apparel building fire incidents recognised through the study. Figure 13 presents the factors according to relevant groups. Left side box of the figure represents the factors identified from literature review and right side box presents the newly identified factors.

Factors contribute to apparel building fire incidents

1) Faulty wiring
2) Welding work with electrical sparks
3) Accumulation of waste fabric materials, garbage and papers
4) Locations of firefighting services in Sri Lanka
5) Building design features/ materials which contributed to the fire development and fire spread
6) Lack of quick response of fire brigade
7) Careless smoking (construction workers are flipped away their cigarette while there are working)
8) Sloppy maintenance on electrical tools
9) Errors in fire detection system
10) Errors in fire protection system
11) Architects' low considerations in fire safety
12) Improper identifications for, fire exits, fire doors, fireman's elevator
13) Integration errors of building design/ architectural features and fire safety system
14) Lack of usage in fire resistant materials
15) Large number of horizontal/ vertical continuous openings
16) Building designing errors
17) Not involving the building for its' original design function
18) Differences between considerations in policies and findings of actual fire incidents
19) Poor equipped fire brigade
20) Lack of staff in firefighting service organizations
21) HVAC system
22) Wooded building structures
23) Lift shafts which its doors removed or opened due to refurbishment

- Deficiencies of commanding at fire scene
- Difficulties in implementing fire related regulations or guidelines
- High cost in installation and maintenance of fire safety system'
- High heat generating machines
- High staff turnover
- Improper chemical storages
- Improper monitoring mechanism of practice of fire regulations and guidelines
- Inadequacy of fire service providers
- Interpretation differences in various fire regulations, standards and guidelines
- Lack of fire training and awareness
- Lack of certified and competent fire protection engineers
- Lack of interest and involvement in fire drills and fire training
- Lack of professionalism in fire service providers
- Lack of safety culture and safety attitudes
- Lack of specific fire regulations for apparel industry Sri Lanka
- Lack of technical knowledge regarding fire safety
- Less focus on passive fire protection
- Less regulations regarding passive fire protection in apparel industry
- Not adhere to standard operation procedures (SOP)
- Outdated factories ordinance Sri Lanka
- Penetration through fire rated barriers'
- Placement issues in several operational functions
- Start fire safety practices in the middle of the business operation
- Sudden breakdowns
- Vague definitions in fire regulations
- Worn out electrical sockets and grounding issues

Figure 13: Factors contribute to apparel building fire incidents

4.3.8 Strategies to Overcome the Identified Factors Which Contribute to Fire Incidents in Apparel Sector Sri Lanka

Although the factors contribute to fire incidents in apparel sector in Sri Lanka, those factors can be overcomed by applying certain strategies. Table 16 presents strategies to overcome identified factors from the study. Strategies have provided for both factors identified from literature review and interviews.

Table 16: Strategies to overcome the identified factors

	Factor	Strategies	Source
1	Faulty wiring	Involve certified and competent electricians Follow IEEE regulations Conduct 'Merger' testing at least once in three years Avoid wiring connections by electrical taps rather than a wire nut or other sanctioned connector	AF1, AF2, CF1, BR1
2	Welding work with electrical sparks	Introduce and hot work permits Use precast elements Install flash-back arrestors in welding machines	BF2, CF2
3	Accumulation of waste fabric materials, garbage and papers	Collect fabric waste at least two times per day Waste segregation Proper understanding on current waste storage in the factory Remove bulky fabric waste from the plant Install fire safety system for waste yard Use covered light bulbs for waste yards	AF1, BF2
4	Locations of firefighting services in Sri Lanka	Establish mechanism to get help from neighbouring facilities Get support from public security authorities (Army, Police, and Civil security department)	CB2, AF2
5	Building design features/ materials which contributed to the fire development and fire spread	Involve fire consultant for building materials and other features selection Use concrete structures instead of steel structures because concrete has more fire retention power than steel.	AF2, CF2
6	Lack of quick response of fire brigade	Strengthen internal fire-fighting mechanism Conduct frequent mock drills and understand their actual capacities	AF1, AR2

		Establish mechanism to get help from neighbouring facilities	
7	Careless smoking (workers are flipped away their cigarette while there are working)	Introduce 'no smoking' policy	AF1, AF2, BF2, CF1, CF2
8	Sloppy maintenance on electrical tools	Conduct proper inspection and maintenance Introduce electrical safety policy Annual electrical testing Maintain inventory for electrical tools and mark the condition of electrical tools	AF1, AF2, CB2
9	Errors in fire detection system	Proper inspection and maintenance Conduct internal audit for fire safety Branded and high quality equipment use Proper inspection by competent staff	AF1, AF2
10	Errors in fire protection system	Proper inspection and maintenance Conduct internal audit for fire safety Proper commissioning and have test runs for fire safety system Branded and high quality equipment use	AF1, AF2, BF2
11	Architects' low considerations in fire safety	Design review with experts in fire safety Educate architects regarding fire safety systems and fire regulations and guidelines Curriculum upgrade	CF1, CF2, AR2
12	Improper identifications for, fire exits, fire doors, fireman's elevator	Use acceptable standardised methods for every element in fire safety system	BR2
13	Integration errors of building design/ architectural features and fire safety system	Consultation from fire protection engineers and architects Involve facilities manager Review the ongoing construction of the building in fire point of view Proper testing and commissioning before occupy the building	AF1, AF2, AB2, CF1
14	Lack of usage in fire resistant materials	Use both cost effective and fire resistant materials Educate relevant parties of the benefits of using fire resistant material Use fire resistant materials for at least places has high fire possibility	AF1, CF1, BR2
15	Large number of horizontal/ vertical continuous openings	Eliminate fire supportive design features Compartmentation Install customised fire safety system to the specific design Install fire-rated glass	AF1, BB2, CR1
16	Building designing errors	Follow proper design guidelines, building codes and standards	AF1, AF2, BF1

		Involved building experts in various professions to the design process	
17	Not involving the building for its' original design function	Proper inspection through Certificate of Conformity (COC) Take necessary fire safety precautions according to current business function Perform alterations accordingly	AR2, BR1, BR2
18	Differences between considerations in policies and findings of actual fire incidents	Periodic policy review and policy review after fire incidents.	CF1
19	Poor equipped fire brigade	Strengthen internal fire-fighting mechanism Inform fire safety department and government about the issue Conduct frequent mock drills and understand their capacities Establish mechanism to get help from neighbouring facilities	AF1, CF1
20	Lack of staff in firefighting service organizations	Strengthen internal fire-fighting mechanism Inform fire safety department and government about the issue Conduct frequent mock drills and understand their actual capacities Establish mechanism to get help from neighbouring facilities	AF1, CF1
21	HVAC system	Cut-off fresh air intakes Install smoke control mechanisms	AF1
22	Wooded building structures	Fire retardant coating for wood Do not use wood as a material for high tropical areas	BF1, CF1
23	Lift shafts which its doors removed or opened due to refurbishment	Consider fire risk even in refurbishment activities Introduce work permits Involve fire watcher	CF2,CB1
24	Deficiencies of commanding at fire scene	Increase the frequency of fire trainings and mock drills	AF2 Respondent-Questionnaire survey
25	Difficulties in implementing fire related regulations or guidelines	Get higher management support Consult relevant local fire authorities Get every employee's suggestions and ideas	CB1
26	High cost in installation and maintenance of fire safety system'	Get financial support from higher management Select suitable service provider	AF1
27	High heat generating machines	Install customised fire safety equipment Isolation of high heat generating machines	BF1
28	High staff turnover	Increase the frequency of training	AB1

		Conduct incentive programmes for well experienced members in fire team Establish good reputation for fire team members within the organisation	
29	Improper chemical storages	Proper understanding on current chemical storage in the factory Install relevant fire safety measures Conduct chemical compatibility tests Use bonding cables to electrically connect containers of flammable chemicals	CF2
30	Improper monitoring mechanism about the practice of fire regulations and guidelines	Appoint competent person for monitor fire safety of the building Maintain checklists Establish accidents, near miss reporting systems	BF2
31	Inadequacy of service providers for fire safety	Establish internal competent staff specially for fire safety system with technology background Inform about the inadequacy of service providers to the government	AF2 Respondent-Questionnaire survey
32	Interpretation differences in various fire regulations, standards and guidelines	Thoroughly review relevant regulations and guidelines and then developed internal policies	BF1
33	Lack of fire training and awareness	Educate employees regarding not only firefighting but also how fire can ignite and how it spread in our working environment	AF2 Respondent-Questionnaire survey
34	Lack of certified and competent fire protection engineers	Develop the job market for professional related to fire safety Conduct professional training programmes	AF2 Respondent-Questionnaire survey
35	Lack of interest and involvement in fire drills and fire training	Conduct monthly meetings with fire team members to get ideas and suggestions	CB1
36	Lack of professionalism in fire service providers	Conduct professional training programmes Establish relevant ethics and professional skills	AF2
37	Lack of safety culture and safety attitudes	Educate employees regarding not only firefighting but also how fire can ignite and how it spread in our working environment Conduct ‘best practice sharing forum’	AR2
38	Lack of specific fire regulations for apparel sector Sri Lanka	Properly follow available fire related guidelines Develop detailed specific fire regulation/ guideline for apparel sector Sri Lanka	CF1, CF2 Respondent-Questionnaire survey

39	Lack of technical knowledge regarding fire safety	Conduct 'best practice sharing forum'	AF2
40	Less focus on passive fire protection	Increase awareness about the importance of both active and passive fire protection measures	BF2
41	Less regulations regarding passive fire protection in apparel sector	Follow available standards and guidelines Conduct thorough review on available standards and develop internal policies Conduct systematic case studies and develop the requirement accordingly	BF1
42	Not adhere to standard operation procedures (SOP)	Conduct awareness regarding use of SOPs Display SOPs near the work station in suitable languages Modify SOPs with the time and according to new learnings	BF2
43	Outdated factories ordinance Sri Lanka	Inform relevant authorities about the issues in current Ordinance and suggest new changes to be made	BF2
44	Penetration through fire rated barriers	Test the conditions of fire rated barriers and reinstall accordingly	BF2 Respondent-Questionnaire survey
45	Placement issues in several operational functions	Consider about the hazardous levels in each and every function according to the risk assessment and placed the functions accordingly Take necessary actions (use fire rated materials, fire barriers etc.)	BF2
46	Start fire safety practices in the middle of the business operation	Educate about the importance of having proper fire safety system from the initial stage	AR2
47	Sudden breakdowns	Conduct frequent testing, inspection and maintenance Maintain backup plans for essential systems	BB2
48	Vague definitions in fire regulations	Develop fire safety policies by referring to existing regulations or guidelines and organisation's business nature	BF2
49	Worn out electrical sockets and grounding issues	Install new electrical sockets Test groundings and make corrections accordingly	AF1

4.3.9 Information of Fire Incidents

Information regarding fire incidents happened in three cases are summarised in Table 17.

Table 17: Details of fire incidents

Category	Case A	Case B	Case C
Time	Night time	Day time but on a holiday	Day time
Ignite location	Building One-Stores	Production Floor	Research and Development workshop
Details of damaged area	10 000 m^2 space totally loss 2500 sewing machines damaged Fabric and administration equipment damaged. Fabric and finished goods in stores Whole telecommunication system damaged	12 500 m^2 space loss Sewing machines, printing machines and embroidery machines damaged Some finished goods also damaged	Whole R&D workshop damaged Adjacent areas also affected Electrical system HVAC system partial damaged
Reason	Electrical malfunction in electric forklift's charger	Electrical short circuit in a power panels	Back fire in gas welding machine

As referred from Table 17, Case A and B had faced similar damages in respective aspects such as loss of gross floor area, damages in sewing and other machines, office equipment, damages to fabrics and some finished goods, while Case C faced certain small damages when compare with other two cases. When considering about reasons for fire incidents, both Case A and B started as electrical fires. Moreover, all three cases had interrupted the business operations. Detailed explanations of each case are discussed comprehensively in the subsequent sections.

4.3.9.1 Fire Incident of Case A

Causes of Fire Incident

According to the Government Analyst's Department Report, fire incident in Case A had happened due to electrical malfunction in forklift's charger. Respondent AF1

explained that *"Forklifts are very dangerous vehicle used in the factories which is different than open road vehicles because it travels in close proximity with large quantity of goods, therefore when forklift move around, it can be a travelling heat source".* Further, he pointed out that this fire started from the charger of forklift which had plugged the day before the incident and had not switched off by the relevant worker. Electrical short-circuit in that charger had caused to ignite the fire.

Description of the Incident

The fire started around 1.00 am on a working day. Since the fire had erupted in warehouse stores, fire had rapidly spread throughout the building. Subsequently, detectors in the stores had detected the situation and had notified to the alarm panel board in the security room. But, the security staff had turn off the alarms because they were sleeping and thought it is a fault alarm. Due to this misbehaviour, fire spread throughout the building. They knew this after around 25 minutes from one of the canteen staff members who saw the fire. Then the security officer had informed the incident to fire brigade. Respondent AF2 emphasised that "Our factory is not in a BOI zone and the nearest fire brigade also 22 kilometres away from the factory. *Therefore it takes around 30 minutes to arrive but they had arrive soon as possible at their best. Moreover, we informed this incident to police and another two fire brigade namely; Kurunegala fire brigade and Army fire brigade also arrived".* After around 6 hours fire brigades had doused the fire with support rendered by residents of the areas.

Consequences of the Incident

Around 4000 employees are employed in the stores, however, there had been no one inside the stores when the fire broke out. Therefore, no injuries had caused but property was heavily damaged. Further, 2500 sewing machines were fully broken and the telecommunication system also damaged.

Action Taken for Fire Incident

According to Respondent AF1: *"First we restricted access to that area and checked CCTV footages for further information".* Government analyst's department had conducted whole investigation process. Moreover, Respondent AF1 added that since

the forklift is a special equipment, which should be vigilant in their safety procedures. Furthermore, Respondent AF1 and AF2 pointed out following precautionary measure.

- Forklift should not be kept or parked in their working place (stores) or places with high fire loads
- Proper training and awareness for forklift operators about fire risk
- Keep forklift clean (avoid to build up combustible residue)
- Follow fire precautions against inherent fire hazard
- Protect battery cables or chargers from damages and replace when damaged

4.3.9.2 Fire Incident of Case B

Causes of Fire Incident

Fire incident of Case B had happened due to electrical leakage in a power panel. Respondent BF1 illustrated that "*This fire erupted in production floor and later on we got to know that it was due to electrical leakage in a power panel, especially, fabric bulk had placed near the power panel which had caused easy fire growth and spread".* Respondent BF2 added; *"Electrical short circuits in power panel occur as a result of electrical flow complete its circuit journey through a short distance than in the recommended wiring".*

Description of the Incident

The fire started in a morning in the New Year holiday season. Fire had erupted in production floor, due to the environment in the production floor and having some material storage resulted in easy spared of fire. Respondent BF2 clarified that *"Even though we have proper fire safety system, one week before this incident happen, our fire alarm system had totally broke down due to lightning issue. But, respective maintenance workers had not repaired it and left it as it is and took their leaves for holidays"*. Due to this issue, fire spread throughout the area without notifying through fire alarms. When the security officers noticed the fire they had took actions accordingly. Fire-fighting unit at the zone, Sri Lanka Air Force and airport had supported to stop the spread of fire to other adjoining factories in the zone.

Consequences of the Incident

No physical damages had reported since the factory had closed down for holidays. But, property damages including damages in sewing machines, printing machines and embroidery machines and also electrical system of the production floor damaged.

Action Taken for Fire Incident

Respondent BF1 highlighted following precautionary measures as actions taken to avoid further fire risk due to electrical short circuits in power panels.

- Test and update wiring system
- Use ground-fault circuit interrupters which are more sensitive and shut-down the flow of current when they identify fluctuations in current. Further, these interrupters are most beneficial to protect the appliance against shocks that can occur in ground-fault type short circuits.
- Conduct proper inspection and maintenance to electrical system

4.3.9.3 Fire Incident of Case C

Causes of Fire Incident

According to Respondent CF1, Case C fire incident happened due to back fire in gas welding machine. Further, Respondent CF1 explained the reason as; "*Gas welding equipment is versatile and easy to move but we should not forget the danger in this equipment. In our fire incident a backfire happened due to gas with higher pressure flowed back through the torch into the hose with lower pressure and this created a dangerous mixture of gases contributed for the fire"*.

Description of the Incident

The incident occurred in a working day morning shift at the R&D workshop area. Two welders who had were involved to this had not used proper safety precautions and unluckily fire detection and protection system also was in a sudden breakdown. Therefore, fire suppressed through manually using extinguishers.

Consequences of the Incident

When compare with other two cases (Case A and B), this case was not caused to major losses. But minor physical injuries happened to welders and R & D workshop and adjoining areas are slightly affected.

Action Taken for Fire Incident

Respondent CF2 emphasised strategies that taken to mitigate future fire risks

- Set regulators to the correct pressure
- Check nozzles are suitable for the type of work
- Keep the nozzle away from any source of ignition until the fuel gas is flowing freely from the nozzle
- Follow hot work permits

4.3.10 Impacts of Fire Incidents in Apparel Sector Sri Lanka

Relevant impacts that can result due to fire incidents in apparel sector Sri Lanka gathered through Annexure I. Seventeen impacts under direct and indirect categories identified through the data collection and present in the Table 18.

Table 18: Impacts of fire incidents in apparel sector Sri Lanka

Impacts	Source
Direct	
Fatalities	AF1
Property damages	AF1
Structural collapses	CF1
Indirect	
Challenges in disposing fire damaged waste materials	AF1
Decrease building strength	CF1
Decrease comfortability in the building or quality of life	CF2
Decrease employees' bond and trust	BF1
Delays in production	BF2
Environmental damages	BF1
Increase expenses (medical expenses, compensation, costs for repairs and refurbishment, and other costs)	BF1
Insecurity in the employment	AF1
Interruptions to building operation	BF2
Loose customers and buyers	AF2
Loss of business goodwill	AF1
Losses in customers' orders	AF2

Lowered moral	AF2
Opportunities create for new learning and modifications	CF1
Service interruption to third parties who use factory's by products to their business (canteen's food waste for farms)	AF1

According to the above impacts, to recover from property damages, structural collapses, decrease building strength, and decreases in comfortability in the buildings refurbishment has to be performed as an initiative to reinstate the building condition as well as to improve the quality of life within the building.

4.3.11 Defining the Term 'Refurbishment'

All six respondents from three cases expressed their opinion this question based on their experiences and knowledge gained by involving different refurbishment activities (Annexure II).

Respondent AR1 uttered the refurbishment as; *"Improvement, upgrading, retrofit and renovation of existing building while recovering the performance or function of the building"*. Further, refurbishment is a critical process which needs to balance both cost and quality requirements of the project. According to Respondent AR2; *"Refurbishment involves updates in building systems, reinstates of deteriorated building elements, re-corrections to early construction errors and to follow new regulatory or policy requirements"*. Cases B Respondent BR1 expressed; *"Refurbishment is a modification of existing structural elements and building services to deliver better environment for the building occupants". "To boost current building conditions to meet new states as well as to uplift existing standards, refurbishment needs to conduct as a future intentional project"* as emphasised by Respondent BR2. Moreover, Respondent CR1 explained refurbishment as; *"A process of upgrading a building to fight against upcoming building related challenges strongly"*. Respondent CR2 clarified the term refurbishment as; *"A task which involves both 'cosmetic' alterations and structural renovations"*.

After analysis of above explanation on the term 'refurbishment', it can be buttressed and encapsulated that refurbishment covers modifications, improvements, upgrades, updates, retrofits and renovation of the existing building to provide better building

performance and environment to building occupants while focusing on building structural elements, building services and building aesthetics.

4.3.12 Reasons for Undertaking Refurbishments in Apparel Sector

Annexure II: Q2 assessed the reasons for undertaking refurbishment activities in apparel sector in Sri Lanka. As pointed out by all respondents, it was evident that refurbishment activities in apparel sector in Sri Lanka are much higher, because of the fact that apparel sector is one of key contributing member in Sri Lankan economy with steady growth rate over the past years. In order to achieve the rapid development, apparel sector has to provide sophisticated solutions to global requirements, applying creativity and experience in the fields namely innovation and R&D which lead to undertake refurbishments.

Respondent AR1 confirmed; *"Apparel sector in Sri Lanka accounting for about half of the country's exports which is one of the top apparel producing countries in the world, therefore, refurbishment provides means to maintain required building conditions and keep up to date functionality".* Apparel sector of Sri Lanka employs nearly fifteen percentage (15%) of the country's workforce and these buildings operate on daily basis including night shifts throughout the year, hence renovations and modifications needed for both structure and building services as stated by Respondent CR2. Further Respondent BR1 emphasised; *"On the other hand, undertake refurbishment to compete with other challenging apparel companies and to enhance aesthetic appearance".* Accordingly, Table 19 has summarised all reasons for undertaking refurbishment in apparel sector.

Table 19: Reasons for undertaking refurbishment in apparel sector Sri Lanka

Reason	Source
To increase building capacity	AR1, CR1
To fulfil sustainability requirements	AR1
To recover building damages and collapses due to an incident	AR1, BR2, CR2
To starts new production lines for novel design requirements	AR1, CR2
To improve building condition	AR2
To improve building functionality	CR1
To enhance aesthetic appearance	BR1, CR2
To maintain requirements of customers (main buyers)	AR1, BR2
To compete with rival apparel companies	BR2

To fulfil legal requirements and policy needs	CR1, BR1
To cater planning forecasts	CR1
To correct existing design or structural errors	BR2, CR2

Accordingly, opinions of the respondents prove that there are many reasons to trigger refurbishment decision and among that 'to recover building damages and collapses due to an incident' can be highlighted as reason which expressed because of the experienced in three past fire incidents.

4.3.13 Key Participants Involved in Fire Refurbishment

Several participants are involved in refurbishment projects in order to gain multi-disciplinary skills and competencies to fulfil purpose of the refurbishment initiative. The success of the refurbishment project is depend on better synchronise between the multi-disciplinary project team. Respondent CR1 explained that *"Composition of the refurbishment team differs from organisation to organisation and depend on the purpose of the projects, and client, building occupants, design team (consultant, architect, quantity surveyor and engineers) and construction team (contractor, sub-contractors and suppliers) can recognised as main three participants involved in refurbishment project*". Especially, Respondent AR2 emphasised; *"Involvement of fire protection engineer is a key requirement for refurbishment projects which the building damaged due to fire incident".* Further, Respondent AR2 explained that FPE is needed to identify key evidences and root causes for fire and to advice accordingly to refurbishment team to minimise future threats to the building.

Respondent AR1 pointed out client, project manager, facilities manager, architects, engineers, building owner, and fire specialist as parties that need to engage in fire refurbishment project. Moreover, Respondent BR1 recognised; *"Client, architect, structural engineer, civil engineer, specialists, mechanical engineer, OSH officer, quality surveyor and contractors*" as parties normally involved in refurbishment project. According to Respondent CR2; site manager, planning engineer, quantity surveyor, contract manager, supplies, sub-contractors, client and financial institutes are the key participants in fire refurbished project. Figure 14 demonstrates key participants involved in fire refurbishment project in apparel sector

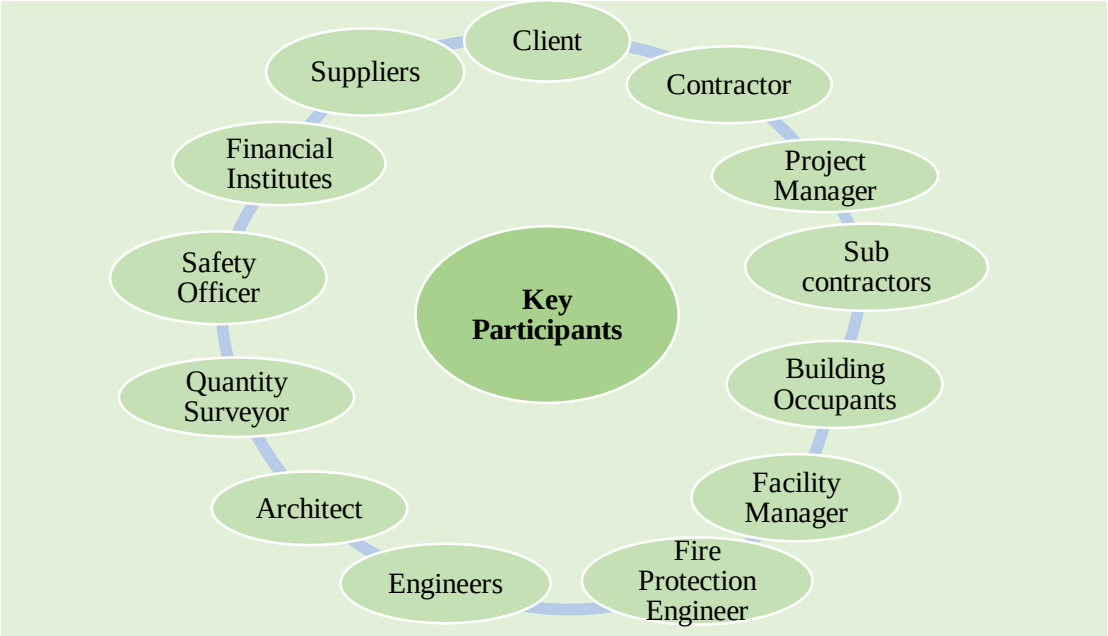

Figure 14: Key participants involved in fire refurbishment

4.3.14 Activities of a Fire Damaged Refurbishment

Respondents explained main activities in fire damaged refurbishment project in apparel buildings according to their knowledge and experience and the responses collected. Being unique from new construction projects, activities of fire damaged refurbishment projects are complex and it is difficult to identify the sequence because of building conditions and state of the fire incident. Stages in fire damaged refurbishment project also same as general refurbishment activity and construction project, such as refurbishment need identification, design stage, tendering and selecting suitable contractor for undertake refurbishment activity. Apart from that, following activities can be recognised as special activities, which performed in fire damaged refurbishment project.

4.3.14.1 Activity 1: Preliminary Survey

According to BR2; *"Preliminary survey is the first step, basically in this stage we should evaluate damages cause by fire such as; fire and smoke damage as well as water damages due to fire-fighting process, before other activities".* Not only that, damages to building structure and building services systems also basically evaluate in this stage. Further, Respondent BR2 emphasised that necessary drawings must be

obtained before visit the site and sometimes unrecorded alternations may have taken place, therefore concern should be given to those new alternations.

4.3.14.2 Activity 2: Detailed Visual Investigation

Detailed visual investigation can be performed to identify cracks, spalling and other damages to the building in detailed. Respondent CR1 illustrated that most of all refurbishment surveys are mainly focused on structural defects and damages as stated*; "Each structural element should be investigated separately to identify severity of defects due to fire incident".*

4.3.14.3 Activity 3: Isolate Unsafe and Hazardous Areas

Respondent BR2 and AR1 stated that 'evaluate the damage cause by fire' activity helps to recognise unsafe and hazardous areas in the fire damaged building. According to Respondent CR1; *"All unsafe areas should be isolated to avoid injuries, accidents and further damages to the building".* This isolation and block off supports to prevent the building from deteriorating as time goes on.

4.3.14.4 Activity 4: Smoke and Soot Removal

All respondents stated that activities used in fire damaged refurbishment projects in Sri Lanka are somewhat differ to global practice. Fourth activity is to remove smoke and soot residue left behind. Respondent BR1 pointed out that; *"To remove smoke and soot, professional experts should involve but in Sri Lanka, finding such experts is very difficult in the field".* Further, respondent BR1 explained that *"Even though we do not practice advanced techniques to remove soot in Sri Lankan context, there are techniques such as 'air-scrubbing' to remove strong smoke smell from the air".*

4.3.14.5 Activity 5: Deconstruction and Perform Refurbishment

According to Respondent BR1, building should be sanitised and cleaned to remove salvageable items. In addition, required demolition activities can also perform to remove unnecessary building elements which can interrupt the refurbishment process. Respondent CR2 explained that there are specialist teams in other countries who are doing fire damaged building restoration and refurbishment. Moreover, Respondent CR1 explained that; *"Refurbishment team restore and reinstate the building to recover*

building from fire damage as well as to meet new requirements as the main activity in refurbishment project".

4.3.14.6 Activity 6: Closure of Refurbishment Project

This is the last activity of completion of refurbishment project. The project participants have to perform their duties and responsibility according to contractual agreements. One of the most important sub-activity in this process is to evaluate, document and learn from the project. Nonetheless, Respondent BR2 explained that; *"Even though the evaluation activity is very important, in the practice, it is not perform effectively due to delays in the project completion and also absence of having proper conditional assessment of early scenario".* Further, Respondent AR2 emphasised that most of all evaluations are focused on building structural stability and therefore, early building functionality or comfortability are neglected. As the final activity, when the refurbishment work is completed according to the requirement, project can hand over to the client or customer.

4.3.15 Challenges of post-fire refurbishment projects

Sixteen (16) challenges recognised in the literature review and the challenges questioned through interviews to identify the level of agreement to the fire damaged refurbishment projects in apparel sector Sri Lanka. Moreover, additional challenges except those found from literature review also recognised through interviews. All six experts in refurbishment projects answered to this question based on their opinion and experience. Table 20 presents the responses for challenges of fire damaged refurbishment projects in apparel sector.

Table 20: Challenges of fire damaged refurbishment projects

Challenges	Strong disagreement	Neither agreement nor disagreement	Strong agreement
Absence of a proper site survey to investigate existing conditions of the building	0%	0%	100%
Impact of noise, vibration, dirt and fume	0%	0%	100%
Unanticipated time overruns	0%	0%	100%

Accumulation of salvaged materials through demolition waste and difficulties in disposal other waste	0%	17%	83%
Insufficient information on original drawings and other functional information	0%	17%	83%
Legislative constraints	0%	17%	83%
Unanticipated cost and financial constraints	0%	17%	83%
Lack of quality standards and parameters	0%	33%	67%
Lack of specialised knowledge and multidisciplinary skills from project participants	0%	33%	67%
Lack of suitable materials to match the existing conditions of the building	0%	33%	67%
Undamaged elements/materials may subject to degradation	0%	33%	67%
Inadequate information on requirements of the client	17%	17%	66%
Introducing changes to existing structure is limited	0%	50%	50%
Lack of proper communication and coordination between project participants	0%	50%	50%
Potential future usages of existing elements may remain uncertain	0%	50%	50%
Unsafe working conditions	0%	50%	50%

According to the Table 20, all the challenges, which have identified through literature are applicable to apparel sector in Sri Lankan context and one respondent has not agreed to 'Inadequate information on requirements of the client'. Further, respondent explained that *"Inadequacy of client's requirements is not a common challenge in refurbishment projects, because client brief provides necessary requirements and expectations of client that assists designers, contractors but when this client brief not sharing at an early stage may makes difficulties to achieve success of the project".*

All Responses marked as strongly agreement for 'Absence of a proper site survey to investigate existing conditions of the building', 'Impact of noise, vibration, dirt and fume' and 'Unanticipated time overruns'. As emphasised by Respondents CR1 *"Time overruns' are very common in refurbishment projects due to refining designs to cater*

unanticipated building conditions and sometimes initial designs may exceed the budget and therefore reviewing new design options also consume a huge time". Moreover, 'introducing changes to existing structure is limited' is also a challenge because certain planned changes could not be incorporated due to architectural and archaeological conditions of the existing structure and limitations in the existing building services systems' layout. Particularly Case A was a good example for the challenge; 'lack of coordination of project participants' because the high involvement of foreign entities as participants for this project.

Respondent BR2 illustrated that accumulation of bulk of salvaged materials through demolition waste is a common problem which is very difficult in convertible them for future uses and also to follow special procedures and regulations to dispose waste materials also consume more time and cost. Furthermore, unsafe working conditions had also observed due to insufficient safety precautions, human negligence and collapse of structural element during constructions. Respondent BR2 explained that; *"Existing materials and elements are difficult to reuse because of dismantling and storing and this had become non suitable and un-matching for future uses".*

Especially, insufficient information of original design and other functional conditions resulted in high dependence on imprecise assumptions to develop design solutions. A respondent buttressed this statement as "*Due to the unavailability of sufficient information about the past functional conditions resulted difficulties in evaluating success of refurbishment project when compare with old building structure".* In addition, lack of standardised parameters and commissioning of building condition also recognised and further explained as *"There are no proper standardised mechanism to evaluate building conditions such as; building services and other comfort levels and therefore this could be pointed out as a noteworthy challenge in refurbishment projects".*

In addition to those found from literature, nine (9) challenges which in fire damaged refurbishment project in apparel sector are newly recognised through interviews. Newly identified challenges are listed as:

- Difficulties in determine contingencies
- Disruptions to refurbishment activity due to simultaneous organisational operations
- Disturbances to other organisational operations by refurbishment activity
- Lack of assessment criteria regarding building services and comfort conditions of previous building
- Lack of standardized mechanism or regulation to follow regarding building fitness prior to the building occupy
- Lack of qualified professionals especially for fire damaged refurbishment
- Security risk
- The involvedness and uncertainty of work
- Unavailability of proper place for secure material storage

Accordingly, altogether twenty-five (25) challenges of fire damaged refurbishment projects in apparel sector Sri Lanka recognised through literature review and interviews.

By considering all these challenges it is evident that the lack of qualified professionals for fire damaged refurbishments, Insufficient information on original drawings and other functional information, lack of assessment criteria regarding building services and comfort conditions of previous building, and lack of standardised mechanism or regulations to follow related to building fitness in terms of structural fitness and fitness of occupancy requirements and comfort before occupy the building; directly as well as indirectly lead to challenge the better recital of BPMs.

4.3.16 Importance of BPM on Apparel Sector in Sri Lanka

All six professionals in three cases were involved to assess the influence of five BPMs on apparel sector in Sri Lanka. Separate questions were raised regarding SP, TP, IAQP, VP and AP. First they were required to give a direct answer as 'Yes' or 'No' for the question and later they explained their answer.

4.3.16.1 Importance of SP on Apparel Sector in Sri Lanka

All six respondents answered to the question by marking 'Yes' or 'No' for whether SP is essential to apparel sector in Sri Lanka. All six respondents marked 'Yes' by

agreeing that the SP is essential to apparel sector Sri Lanka. Then respondents were required to give explanations for their choice.

Respondent AB1 and CB1 explained that the apparel sector in Sri Lanka is a human intensive sector which required to fulfil adequate special requirements in order to facilitate their work and wellbeing in comfortable manner. According to BB1; *"As an organisation in apparel sector, we need to pay more attention to SP to avoid accidents and near misses related to poor SP which is the highest accident type in apparel sector".* Respondent AB2 added; *"SP is an important aspect specially in maintaining ergonomics requirements and work study division is the responsible party who focus on special requirements and ergonomic concerns especially in production floor".* Moreover, Respondent BB2 stated that it is a legal requirement according to Factories Ordinance to maintain necessary spatial requirements in the factory. Apart from that, SP is essential to decide required machine layouts and to plan workplace settings as pointed out by Respondent CB2. Further, Respondent CB2 explained; *"We need to have adequate special requirements to perform maintenance activities in a safer manner. As an example we have already identified high risk areas in our factories. For those areas, there are limited access and therefore employees will have limited exposure. Specially, some very high risk areas are isolate from general occupants. Accordingly, when the absence of having SP, we cannot establish those protective measures".*

4.3.16.2 Importance of TP on Apparel Sector in Sri Lanka

All six respondents marked 'Yes' by agreeing that the TP is essential to apparel sector Sri Lanka. Then respondents gave explanations for their choice with past incidents.

Respondent BB1 explained that *"Apparel sector organisations used high heat emitting machines, therefore TP is essential to maintain correct thermal conditions in the organisation".* Thermal conditions may create certain issues in fabric materials and further it explained by Respondent CB1 as *"TP is very important to apparel sector. Because, thermal condition may create certain issues in the fabric materials. As an example due to sweat and moisture which create from thermal conditions, curling effects and stains can be seen in the fabrics. Therefore, TP is an essential consideration*

in material point of view, which directly affect to the product quality". Moreover AB2 illustrated that TP presents high cost in apparel sector regarding the energy cost in air conditioning systems. Apart from that different employees need different thermal levels to perform their work in effective manner and therefore proper considerations in TP is needed. Specially, Respondent CB2 pointed out some interesting fact about TP as *"Due to a major breakdown in our central air-conditioning system, we had to close down the factory for one day because of employees rejected to work without air conditioning and it could affect to product quality as well as".* Finally, Respondent CB1 stated that *"I think out of all the other performance mandates, TP is the key concern in apparel sector".*

4.3.16.3 Importance of IAQP on Apparel Sector in Sri Lanka

All six professionals of BPMs decided that IAQP is essential on apparel sector in Sri Lanka. Then respondents gave explanations for their selection.

Respondent AB1 mentioned that there are more than 2000 employees work in the production floor of Case A and due to this situation indoor air pollution can be higher, which impacts to their health conditions if the IAQP is neglected. This situation further highlighted by Respondent BB2 as *"IAQP is a key consideration in apparel sector because employees have to deal with fabric materials throughout their working time. Even though fabric materials undergone testing procedures regarding fabric dust, there is some sort of dusts in air due to nature fabric materials. And these dusts can mix with air-condition system and it is directly impact to occupants health conditions".* As a health concern which reflect most of the time in long run, it is essential to maintain proper chemical practice in order to safe guard employees from poor IAQP due to high VOC compounds in air as explained by Respondent CB1. In addition, CB2 asserted that *"Indoor air quality need to be maintained to minimise machine breakdowns due to dust accumulation and to avoid sick building syndromes".*

4.3.16.4 Importance of VP on Apparel Sector in Sri Lanka

VP is essential to apparel sector in Sri Lanka and it was confirmed by all six experts in three cases. Following explanations further explained their opinions.

Respondent AB1 emphasised that employees in apparel sectors always deal with sensitive works which required quality lighting conditions in order to produce garments in good quality while mitigating health issues. Respondent BB1 and CB2 added to Respondent AB1 statement as *"Proper visual conditions facilitate employees to perform their work in effective and efficient manner which ultimately produce large quality output".* On the other hand, Respondent AB2 claimed; *"Not only lighting conditions but also visual appearance in the working environment in the factory need to be maintained to attract and retain employees".* Moreover, Respondent CB1 expressed *"Sometimes it is very difficult to maintain required lighting levels in the same floor, therefore we use task lighting techniques and this leads to increase workers' focus, lower errors and avoid defects products passing on to the next stage".*

4.3.16.5 Importance of AP on Apparel Sector in Sri Lanka

As other four BPMs, AP is also identified as important to apparel sector in Sri Lanka by all six respondents.

Respondent CB1 stated that acoustic environment is directly related with occupancy health condition and therefore it is essential to maintain good AP in the organisation. In fact, poor AP can create long term health impacts. Respondent AB2 asserted; *"Apparel organisations use high noise generating machines such as sewing machines, generators, boilers, chillers, etc. apart from that sewing machine workers expose to this sound throughout their working hours therefore AP is essential in apparel sector".* Importantly, AP has a significant role not only in physical health but also in mental well-being as claimed by Respondent BB1. Respondent CB2 declared; *"Maintain established acoustic levels is a legal requirement and a customers' requirement which need to follow to get annual approval for factory from local authority and to increase order levels as well".*

4.3.17 Involvement of Regulations and Guidelines Related to BPMs in Apparel Sector

All six respondents of three cases were involved to investigate the involvement of regulations and guidelines related to BPMs. All respondent emphasis that there is a need to preparing regulations regarding BPMs specially focused on apparel sector Sri

Lanka. Further Respondent CB1 pointed out; *"Apparel sector is the largest and most diverse contributor to Sri Lankan economy and not only that apparel sector employs 15% of the country's workforce, therefore by considering the complex nature in apparel sector and its workforce, it is essential to create apparel sector specific regulation".*

Respondents of three cases claimed that Factories Ordinance is the main legal regulation in Sri Lanka related to BPMs of apparel sector. Respondent AB1 stated that *"Factories Ordinance mainly focus on fire safety in the building, therefore less focus can be seen in BPMs. But vague or general statements can be found regarding space requirement for one person, temperature, ventilation and lighting".* Moreover, Respondent BB1, BB2, and CB2 highlighted about the BOI guideline which further support to maintain BPMs under Section 2 and 4, but all of them agreed to the insufficient detailed information regarding BPMs in the guideline. Therefore, all cases follow different standards and guidelines such as; standards of ISO, ASHRAE and American Conference of Government Industrial Hygienists.

Respondent AB2 in Case B recognised Walt Disney International Labour Standard as the main customer requirement followed in the organisation. Further Respondent AB1 explained; *"Code of conduct for manufacturers in Disney Standard has mentioned to provide adequate lighting and ventilation to employees under health and safety section".* Case C mentioned the Occupational Exposure Level Control Plan as their policy which covers BPMs. Respondent CB1 explained; *"Occupational Exposure Level Control Plan addresses most of the requirements of BPMs under sub sections of hearing protection, illumination, nuisance respirable dust level fugitive emission level, and air temperature, relative humidity and heat stress measurements".* NIKE compliance tool recognised as the customer guideline for Case B and Respondent BB1 stated; *"We have developed our own policy by referring best practices in the sector, legal requirements and customer requirements as well".* Furthermore, Respondent CB1 highlighted; *"There should be proper regulations regarding BPMs especially for apparel sector or at least standards to follow otherwise there will be lack of focused and priority may be less on the mandates".*

4.3.18 Acceptable Requirements of BPMs

Respondents were required to identify physiological, psychological, sociological, and economic requirements of five BPMs. Findings regarding four acceptable requirements are tabulated in Table 21. Requirements of BPMs under four acceptable criteria which were recognised both from literature review and interview findings are represented in light orange colure cells as well as light green colour cells are presented requirements which newly recognised through interviews.

Table 21: Acceptable requirements of BPMs in apparel buildings

	Physiological Requirements	Psychological Requirements	Sociological Requirements	Economic Requirements
SP	No. of employees	Privacy for occupants	Interaction of occupants	Budget constraints
	Ergonomic comfort	Systematic arrangement of space	Easy access to sky garden where could provide private space	Conversion of materials and other resources
	Handicap access	Habitability	Wayfinding's	Cost
	Functional servicing	Changeable spaces	Functional adjacencies	Space conservation
	Building services requirements	Open space arrangements	Informal office arrangements	Energy targets
	Space need for employees	Excellent design to provide a 'high volume, low density' experience	No. of employees who are prefer to use the space	Quality considerations
	Space need for furniture	Wayfinding through creativity but unambiguous	Habits and preferences which developed through social and cultural influences	Use sustainable materials for building
	Space requirement for maintenances	View, beauty, calm and excitement aspects	Formed teams or groups in the working space	Green designs
	Separation of work tasks into zones	Convenience transportation media through spaces (elevators)	Customer or buyers requirements	Involvement of lean concepts
	Adequate safe for welfare facilities (sanitary convenience, washing facilities, drinking water, changing rooms & rest rooms)	Indoor office plants		
	Lightning requirements	Increase roof height to feel less crowd		

	Access requirements	Suitable colours		
	Required safe distances	Employees' prefer time to use the place		
	Isolations or exposure controls			
	Relevant signs and labels			
	'Dancing Modules' concept			
	Requirements for flexibility or future growth			
TP	Influences from air temperature, air velocity, radiant temperature & relative humidity	Individual controls	Flexibility to dress	Cost
	Uniformity of condition	Healthy plants	Others' contagion effects	Budget constraints
	Clothing	Natural ventilation	Social belief about air-conditioned factories	Energy conservation
	Metabolic heat	Expectations	Customer or buyers requirements	Occupancy load
	Wellbeing and sickness	'Thermal alliesthesia'		Green roofs to reduce thermal load
	Natural or mechanical ventilation	PPE		Operation time secludes
	PPE			Quality / Defects
	Acclimatisation			
	Heat stress levels			
	Flexible working times or schedules			
	Comfortable uniforms			
IAQP	Space planning according to nature of work regarding IAQ	Belief and imagination	Others' contagion effects	Cost

	PPE	Signs and labels at hazardous areas	Customer or buyers requirements	Energy conservation
	Material selection & specifications	Special attention and concerns of pregnant workers	Placement of chemicals to near boundary	Third party approvals
	Building openings	PPE		Quality / Defects
	Air purity			
	Employees distribution			
VP	Floor area	Appropriate lux levels	Sense of territory	Cost
	Appropriate lux levels			Energy conservation
	Building envelop and orientation	Low heat emitting lights/ cool white lights	Customer or buyers requirements	Material Third party approvals
	Design of openings			
	Occupancy factor	Design of openings		Quality / Defects
	Task lighting	Green workplace techniques		Techniques – sensors, shades, solar
	Interaction of task			
		Interior colours (eye pleasing colours)		
		Daylight integration		
AP	External noise minimisation	Quiet, soothing	Privacy and communication	Cost
	Internal noise minimisation	Music enjoyment – PA systems	Factory boundary noise levels and social impacts due to that	Energy conservation
	Vibration minimisation	Involvement of staff to PPE selection	Customer or buyers requirements	Material
	Speech clarity	PPE		Third party approvals
	Isolation			Quality / Defects

4.3.19 Best Practices of Maintaining BPMs in apparel sector

All respondents revealed answers according to their organisational practice and nature. Current best practices including measuring techniques have presented for five BPMs separately.

4.3.19.1 Best Practices of Maintaining SP in apparel sector

Industrial Engineering Technology (IET) team in the Case C is acted as the main responsible party to maintain SP in the organisation. Respondent CB1 explained; *"IET team basically investigate spatial arrangements, employee factor, material flow, machine maintenance requirements to obtain time reductions in the production process as well as to enhance total SP in the organisation".* Respondent CB2 stated that Lean Audits and 5S Audits are conducted specially focus on SP. In addition, internal ergonomics surveys are conducted annually and prepare action plan accordingly to get corrective action against findings in the survey. Moreover, 'Change Management Policy' for any changes in workplace setting and Respondent CB1 pointed out; *"We follow 'General Work Environment Policy' in the factory. In this policy we have mentioned about required space for different activities, disability access, adequate space per person, required free distance from high risk machineries*". Respondent AB1 mentioned that still they only follow 5S concept in the office section but maintain SP in waste yards by waste segregation and isolation to minimise risk. Further, Respondent AB2 claimed; *"We conduct period maintenance plans for production flow to identify special deficiencies which lead minimise time waste".* Apart from that, specifically focus given to Near Misses Reporting System because, generally majority of near misses are regarding inefficient SP in the organisation. Case B practice is somewhat different from other two cases. Case B is involved team leaders to monitor spatial arrangements in sewing operation section and other than this, health and safety team members investigate spatial conditions in other areas. As Case A, Respondent BB2 emphasised that Case B also do not follow 5S concept for the factory.

4.3.19.2 Best Practices of Maintaining TP in apparel sector

Case C revealed about the 'Occupancy Exposure Control' policy, which is the main guideline to maintain TP in the organisation. According to the Occupancy Exposure Control Policy, defined thermal requirements for different work places are evaluated.

Respondent CB2 stated that *"Involve a third party to measure and evaluate TP quarterly and apart from that engineering teams take daily measurements regarding TP in the organisation".* Further, Respondent CB1 mentioned; *"There are indicators for humidity and temperature levels in the production floor and we start the air-conditioning system 30 minutes prior to the factory operation as a best practice in the sector".* In addition, Respondent BB1 mentioned; *"Our engineering team is the main responsible party regarding TP. They take readings in thermostats and enter these data into a register".* Respondent AB2 illustrated that they involve separate third party for air-conditioning maintenance in the organisation and apart from that internal staff involves for general troubleshooting and cleaning once in every two weeks.

4.3.19.3 Best Practices of Maintaining IAQP in Apparel Sector

According to the Occupational Exposure Control Plan of Case C, nuisance respirable dust level and fugitive emission level are measured. Respondent CB1 explained; *"Nuisance respirable dust level is monitored annually by an accredited party and we maintain 0.20 mg/m3 as the Threshold Limit Value for respirable fabric dust".* Volatile organic compound test is conducted annually in the areas of potentially high fugitive emission levels such as printing units, and dye houses as stated by Respondent CB2. Apart from that, lung function test is conducted annually for all employees exposed to high fugitive emission. Respondent CB1 further explained that; *"Lung function test is recommended to carry out prior to assigning a new employee to a high exposure area and then the results of the initial lung function test is used as the valid baseline against which subsequent lung function tests".* Respondent BB2 revealed that they perform vacuum cleaning for dust accumulated areas in the air-conditioning system and filters. In addition, dust masks need to be worn by all employees who in an area posted for high level of dust. Insist, Respondent AB2 claimed that; *"Even though dust masks provide free of charge to all relevant employees and selection is given to them, employees' reluctance to wear dust masks can be noticed".* Moreover, Respondent AB1 stated that there is no any practice to monitor IAQP regularly in the organisation but to attend if any complaint received regarding poor IAQP.

4.3.19.4 Best Practices of Maintaining VP in Apparel Sector

Respondent AB1 emphasised that engineering team takes lux level measurements for specific locations such as checking tables, needle point. Respondent AB2 mentioned; *"We have increased the roof height to reduce shadow effects and have used eye pleasing colours for most of the places in the organisation".* Respondent BB2 explained that illumination levels are monitored annually by an authorised party and apart from that Respondent BB1 stated that *"A lux meter is available with the divisional energy and sustainable team and they carry out internal testing where necessary".* As Case A and B, Case C also provides task lighting and maintain required lux levels according to work tasks. Apart from that, sky lighting, glass facades and solar tubes lights use an alternative lighting techniques. Respondent CB1 explained; *"Solar tubes are sheet-metal tubes with a polish interior and this interior acts as a continuous mirror which capture daylight at the roof and delivers it inside the building. Most of all time, this tubes spread light in a pure white glow".*

4.3.19.5 Best Practices of Maintaining AP in Apparel Sector

Respondent AB1 explained that regular inspection and repair of any loose connections in machines are conducted to reduce noise generation and use sound insulated rooms for generator and boilers. Respondent AB2 mentioned that *"We provide hearing protections to all employees who work in high noise areas which Time Weighted Average exposures equal or exceed 85 decibels".* Case C revealed that audiometric tests are conducted for workers who expose to high noise generation areas by a certified audiologist. Respondent CB2 explained; *"We conduct audiometric tests for any team member recruited for the high noise area and he or she should undergo audiometric test within 3 months of the recruitment".* In addition, indoor and boundary noise levels are monitored annually by an authorized party. Embroidery machines, air compressors, knitting machines, boilers, generators, high frequency cutting machines, sewing machines and print washing area using high pressure guns identified as the high noise generating sources in three cases.

4.3.20 Current Challenges of Building Performance in Post Fire Refurbished Apparel Buildings

The respondents pointed out the forty-five (45) challenges encountered in maintaining building performance of post fire refurbished cases. Table 22 elaborates challenges regarding five BPMs in post fire apparel buildings.

Table 22: Challenges regarding BPMs

BPMs	Challenges
SP	High cost for changes in and maintaining spatial arrangement
	Frequent design changes of production floor
	Employees' reluctant to follow established spatial arrangements
	Frequent pathways block during production
	Mismatch between designed space and current operation
	Recruitment conduct without considering on the available space
	Lack of having apparel sector specific regulations for SP
TP	Evaporative cooling mechanism affects to product quality
	Humidity issues in printing section
	Employees complaints regarding their uniform
	Lack of upgraded air conditioning load according to changes in workforce and modification
	High operation cost regarding air conditioning system
	Lack of having apparel sector specific regulations for TP
	Discomfort when air-conditioning system is break down and all openings are sealed
	Lack of uniformity in air-conditioning distribution throughout the factory
	Employees' misbehaviours
	Heat transfer from roof
	Heat transfer from glassed areas
	Complaints regarding air-conditioning levels in shift changing time
	High heat emitting machines
IAQP	New materials which contain dusty compounds

	Difficulties in collect fine fabric particles in the operation
	Reluctant to use personal protective equipment
	Lack of having apparel sector specific regulations for IAQP
	Financial challenges for machine isolations
	Lack of having proper tools to measure and evaluate IAQP
	Toxic fumes can accumulated in walls, duct systems etc
VP	Frequent changes in machine layouts without considering lighting positions
	Discoloration of wall paints
	Distracts due to sensor lightings
	Effects of dust, water and oil on lighting bulbs
	High cost for testing and evaluation of damaged lighting system
	Lack of having apparel sector specific regulations for VP
	Lack of having proper tools to measure and evaluate IAQP
AP	Distractions to some employees and to office area due to music broadcast by PA system
	Unnecessary noise generation due to improper AC duct design
	Unnecessary noise generation due to sewing machines
	Vibration in flat seam, straight knife cutting and other machines
	Reluctant to use PPE
	Lack of having apparel sector specific regulations for AP
Contradictory in SP vs. AP	
Contradictory in SP vs. TP	
Contradictory in VP vs. SP	
Contradictory in IAQP vs. TP	
Contradictory in IAQP vs. SP	

Frequent design changes of production floor recognised as a challenge related to SP. Respondent BB1 explained; *"Due to the frequent design changes, spatial arrangement in the factory is affected. New designs are normally involved at least once in every six months, at that time we have to change the machine layouts as well as specific space*

given for employees. This is a very difficult task which cannot be properly fulfil". Respondent AB2 emphasised that factory's recruitment process is conducted according to the order levels and other HR requirements. But, they forget to consider about available space for employees. This issue creates improper spatial arrangements as well as insufficient space for employees. Respondent CB1 highlighted a challenge according to a past incident as *"This was happened in few years back. We wanted to convert one of the buildings as a sustainable building. We installed evaporative cooling instead of having air-condition system, at that point when we stored finished goods in that area, fungus grown in fabric due to a humidity issue".*

Respondent AB1 pointed out that most of the times, depend on the customer requirement factory cannot change the fabric materials for some designs. When these materials are involved in cutting process, high amount of fabric dust can be created. Another challenge is accumulation of toxic fumes in structure. Respondent BB1 explained this situation; *"After a fire incident, there is a hidden impact of soot. Hazardous and toxic particles can stick to surrounding surfaces such as walls, ceilings and duct system which can create air quality issues".* Some issues in sensor lights mentioned as a challenge in VP by Respondent AB1. Respondent AB1 shared the experience; *"As we all know, sensor lights save our energy. But I have experienced an issue regarding this sensor system. We use sensors for meeting rooms and for that meeting we have had to review a report, therefore there were not such noticeable movements. At that time lights were frequently switch off and on which made a huge uncomfortable situation to us".* Distraction creates from PA system/ music system is recognised in all three cases. They explained that this PA system is used to broadcast songs as a mind relaxing method. But this creates some uncomfortable noise to those who do not like the songs broadcast and specially to the office areas.

Moreover, five contradictory situation pointed out by respondents. To have a smooth process flow, relevant machines and processes placed according to the process flow chart. But, if there are high noise generation machines, these machines have to isolate them as a safety measure but it will compromise the process flow. Similarly, high heat emitting machines and toxic chemical use processes cannot placed according to the process flow and in the same production area, relevant isolation strategies have to

follow. Respondent AP1 explained that; *"Sometimes we change the special arrangement according to some designs or to new requirements, but existing lighting arrangement and its' positions are not suitable for new space setting".* Lastly, there is a challenge in providing air conditioning facility to areas which use toxic fumes and chemicals. Separate special air-conditioning system have to install without taking return air from the hazardous work area.

4.3.21 Strategies to Overcome the Identified Challenges

Respondents provided solutions according to their knowledge and experience as tabulated in Table 23.

Table 23: Strategies to overcome the identified challenges

BPMs	Challenges	Strategies to overcome
SP	High cost for changes in and maintaining spatial arrangement	U shape, and dancing production modules to optimise space plus production and save cost
	Frequent design changes of production floor	Maintain proper relevant plans and documents regarding frequent work station changes Develop pre-plans for future orders
	Employees' reluctant to follow established spatial arrangements	Educate employees from the beginning (at the induction sessions) and frequently Establish reporting channels to notify misbehaviours
	Frequent pathways block during production	Provide awareness regarding SP in production floor Regular checks and corrections
	Mismatch between designed space and current operation	Evaluate the available space of the organisation and analyse with the production requirement
	Recruitment conduct without considering on the available space	Evaluate the available space of the organisation and analyse with workforce factor
	Lack of having apparel sector specific regulations for SP	Request to government enforce apparel sector specific SP regulations Developed internal detailed policy to cover SP requirements
TP	Evaporative cooling mechanism affects to product quality (fungus growth)	Maintain correct humidity levels
	Humidity issues in printing section	Measure and control the level of humidity Use dehumidifiers
	Employees complaints regarding their uniform	Considers employees' suggestions regarding uniform or allow them to sew their own uniform adhere to the standard with their preferable material
	Lack of upgraded air conditioning load according to changes in workforce and modification	Conduct proper evaluation about the air condition requirement of different locations

	High operation cost regarding air conditioning system	Provide separate split air-conditionings without central air-conditioning to areas which only work for few hours (cutting section)
	Lack of having apparel sector specific regulations for TP	Request to government enforce apparel sector specific TP regulations Developed internal detailed policy to cover TP requirements
	Discomfort when air-conditioning system is break down and all openings are sealed	Proper maintenance on air-conditioning system Keep easy operable openings
	Lack of uniformity in air-conditioning distribution throughout the factory	Measure and evaluate air-conditioning requirements and current situation Eliminate cooled air wasting places
	Employees' misbehaviours	Educate employees regarding TP
	Heat transfer from roof	Use sandwich panels for roof
	Heat transfer from glassed areas	Use heat reduce stickers for glass
	Complaints regarding air-conditioning levels in shift changing time	Increase air-conditioning level only for the specific period Educate employees about the issue and its reasons
	High heat emitting machines	Isolation Use low heat emitting or modified machines
IAQP	New materials which contain dusty compounds	Minimise the involvement of dusty fabrics Use in-built dust sucking modified machines
	Difficulties in collect fine fabric particles in the operation	Install special sucking tubes for fabric cuttings areas Install in-built fabric dust sucking system in modified cutting machines
	Reluctant to use personal protective equipment	Educate employees about the importance of PPE
	Lack of having apparel sector specific regulations for IAQP	Request to government enforce apparel sector specific IAQP regulations Developed internal detailed policy to cover IAQP requirements
	Financial challenges for machine isolations	Educate higher management about the issue, possible solutions and positive outcomes
	Lack of having proper tools to measure and evaluate IAQP	Get higher management support and financial support to buy relevant tools

	Stick of toxic fumes in walls, ceiling and duct systems etc.	Complete building flush after fire incident Proper testing before occupy the building Purge whole building after fire Install filters for smoke and dust in duct systems
VP	Frequent changes in machine layouts without considering lighting positions	Check correct positioning of lights after layout change Provide task lights for places which do not have adequate lighting
	Discoloration of wall paints	Regular maintenance and repairs
	Distracts due to sensor lightings	Provide additional controls Increase the consider time period for identify any motion
	Effects of dust, water and oil on lighting bulbs	Regular cleaning and repairs
	High cost for testing and evaluation of damaged lighting system	Get higher management support and financial support by inform them about the importance of this work
	Lack of having apparel sector specific regulations for VP	Request to government enforce apparel sector specific VP regulations Developed internal detailed policy to cover VP requirements
	Lack of having proper tools to measure and evaluate IAQP	Get higher management support and financial support to buy relevant tools
AP	Distractions to some employees and to office area due to music broadcast by PA system	Proper sound insulation of office areas Use low or required volume in PA system Schedule the broadcasting time
	Unnecessary noise generation due to improper AC duct design	Proper tightness and fixing in duct system and change the unnecessary turns
	Unnecessary noise generation due to sewing machines	Regular maintenance on machines Consider about noise when selecting machines
	Vibration in flat seam, straight knife cutting and other machines	Job rotation
	Reluctant to use PPE	Educate employees about the importance of PPE

	Lack of having apparel sector specific regulations for AP	Request to government enforce apparel sector specific AP regulations Developed internal detailed policy to cover AP requirements
Contradictory in SP vs. AP		Prioritise the BPM Isolation Use sound barriers or absorbance Install high frequency cutting machines
Contradictory in SP vs. TP		Prioritise the BPM Isolation Use low heat emitting machines
Contradictory in VP vs. SP		Prioritise the BPM Pre plans the tasks
Contradictory in IAQP vs. TP		Prioritise the BPM Install separate air-conditioning system Use organic, or zero discharge hazardous chemicals
Contradictory in IAQP vs. SP		Prioritise the BPM Use organic, or zero discharge hazardous chemicals

4.3.22 The Framework to Enhance the Performance of Buildings Beyond Restoration

Through the discoveries of the literature review, interviews and questionnaire survey, a framework was established in order to accomplish the aim of the research, which is to examine building performance of post-fire refurbished buildings in apparel manufacturing sector in Sri Lanka. Accordingly, section (4.3.22.1) is presented the stages in framework development and developed framework.

4.3.22.1 Stages in Framework Development

1. Present Key Themes

The first stage in framework development is the present key themes. Accordingly, the framework was developed based on following three main themes in the research, namely;

- Building fires in apparel manufacturing sector
- Refurbishment of fire damaged building
- Building performance of post-fire refurbished apparel building

These three themes were involved to recognise 'Push Factors', 'Pull Factors' and inter-relationship between identified factors.

2. Identification of Push Factors

Push factors refer to conditions or aspects, which trigger or drive the key themes in the framework. Push factors can be recognised based on the pre-defined key themes. Therefore, these push factors can be acknowledged as positive or negative merely based on the theme. Accordingly, push factors for three themes were identified as and present in Table 24.

Table 24: Push factors of the framework

Themes	Push Factors
Building fires in apparel manufacturing sector	• Factors contribute to fires in apparel building
Refurbishment of fire damaged building	• Reasons for undertaking refurbishment project • Key participants in post-fire refurbishment project

	• Activities in post-fire refurbishment project
Building performance of post-fire refurbished apparel building	• Importance of BPMs • Regulations and guidelines of BPMs • Best practices of BPMs • Acceptable requirements of BPMs • Strategies to enhance BPMs

3. Identification of Pull Factors

Pull factors discuss about the conditions or aspects which prevent or block the key themes in the framework. Pull factors can also be recognised based on the pre-defined key themes. As push factors, these pull factors can be acknowledged as positive or negative merely based on the theme. Accordingly, pull factors for three themes were identified as and present in Table 25.

Table 25: Pull factors of the framework

Themes	Pull Factors
Building fires in apparel manufacturing sector	• Fire safety systems • Fire safety teams • Regulations and guidelines
Refurbishment of fire damaged building	• Challenges in post-fire refurbishment projects
Building performance of post-fire refurbished apparel building	• Challenges of BPMs

4. Determine the Inter-relationships

Fourth stage was determine relevant inter-relationships for the framework. Inter-relationship and flow of the framework were determined based on the identified themes, push factors and pull factors. This inter-relationships are useful for better understanding the whole picture of the developed framework.

5. Develop the Framework for the Study

Final stage was to develop framework for the study. By considering all above four stages and the factors and conditions identified were involved and considered for framework development. Figure 15 is encapsulated the research findings and presents framework to enhance the performance of the building beyond restoration.

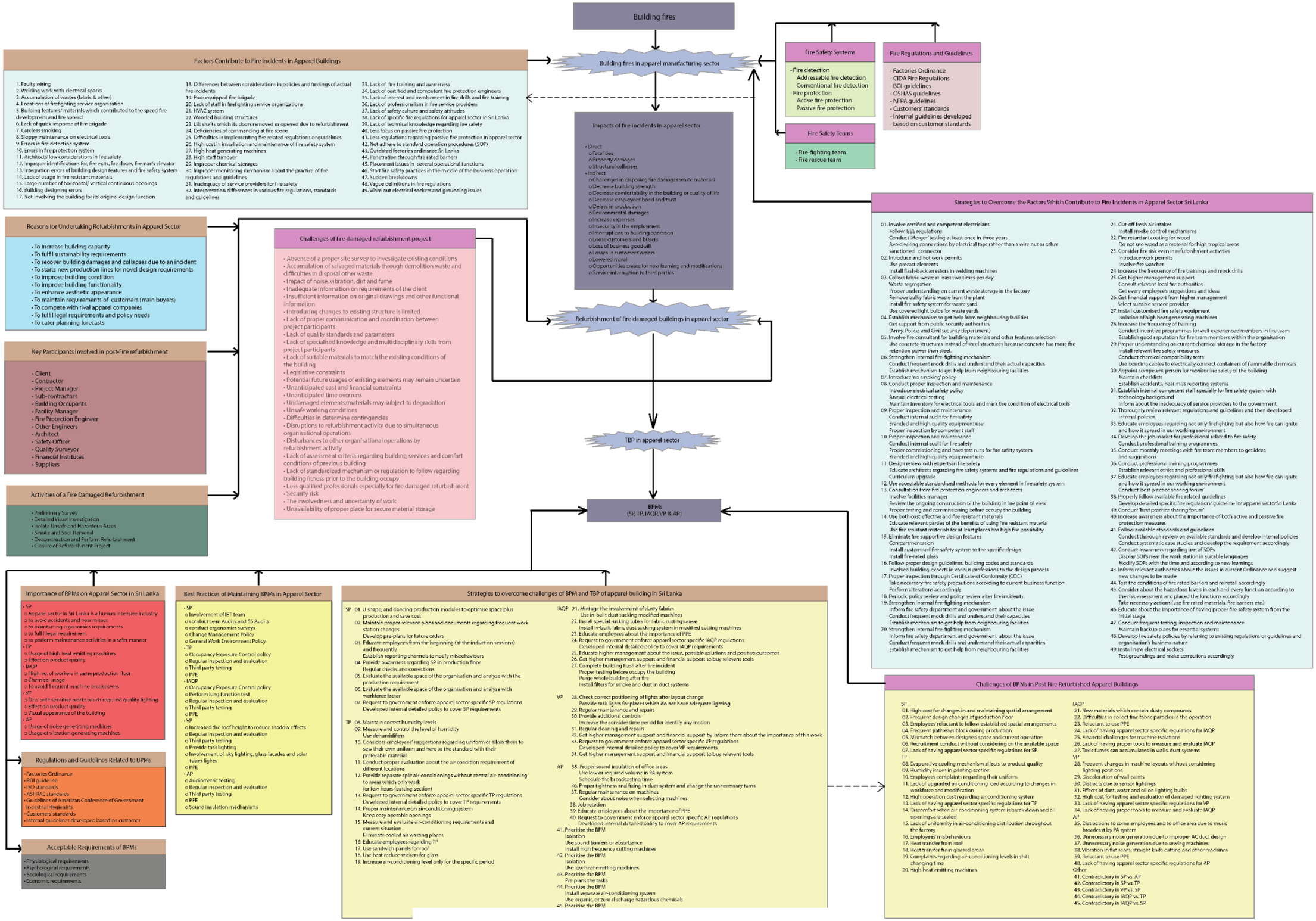

Figure 15: Framework to enhance building performance beyond restoration

4.4 Discussion

This section discusses results and literature findings for enhancing building performance of fire damage refurbished buildings of apparel sector. Similarities and dissimilarities between literature finding and real data, major research findings acquired from the analysis with explanations, trends and regularities in the collected data were presented in this section.

4.4.1 Fire Risk and Fire Safety in Apparel Sector

The present research offered certain insights to fire risk and safety in apparel sector buildings. Initially, 'why fire resistant building is still a major challenge worldwide' was investigated as a better beginning for evaluation of fire risk in apparel buildings. Chow (2005) mentioned that fire resistant building is still a major challenge worldwide, even though there are plenty of active and passive fire safety measures have involved. Further, Liu et al. (2012) emphasised; although the present fire related technology is in high end, fireproof buildings are still a worldwide solution seeking problem. Accordingly, current research identified nine main reasons, which act as a reasons for the inability to protect buildings from fires. Technical gaps and errors, human errors, not following the standards and regulations, budget constraints, lack of maintenance, errors in fire assessments, failures in fire audit, lack of consideration in passive fire protection, and low consideration about fire safety at the initial stage of the design recognised as reasons for this challenge.

Islam and Roman (2019) stated that fire hazard is an ongoing critical issue in the apparel sector over the past decade. Eighty-three point four percent (83.4%) respondents in the current study specified there is high fire risk in apparel sector in Sri Lanka and only one respondent stated it as a moderate risk. High fabric storages, chemical usage, usage of machineries, frequent staff turnovers expressed as attributes which trigger the fire risk in apparel sector in Sri Lanka.

The literature highlights the better symbiosis between hardware and software measures of fire detection, notification and suppression need to involve to effectively fight against building fires (Halliday & Booth, 2019; Han & Lee, 2009; Ono, 2003). Reflecting the findings from three cases in the current study, smoke detectors, heat

detectors, pull stations, and beam detectors have installed as elements in fire detection system. Next, fire alarm control panel, primary power supply, secondary power supply, fire alarm notification appliances such as horns, sirens, bells, speakers identified under fire notification system. Findings revealed that even though all three cases have installed addressable fire safety system, advance features such as automatic closing of fire doors in corridors and notification to relevant public emergency respondents are absent in selected cases. Moreover, lack of consideration on passive fire safety measures pointed out through the findings of current study. Advance early fire detection techniques involve as a preliminary firefighting method (Liu et al., 2012). Han and Lee (2009) and Wei et al. (2013) recommended ultraviolet and infrared detectors, particle sampling, relative humidity sampling, smoke analysis, temperature sampling and transparency testing as advance early fire detection techniques. However, three cases revealed the advance early fire detection techniques are really used in apparel sector in Sri Lanka other than the infrared image testing.

Main stream literature identified code and standards of NFPA, Fire regulations of CIDA, mandatory structural fire protection and access requirements of Fire Service Department and fire safety requirements of Urban Development Authority as commonly refer fire regulations in Sri Lanka. Moreover, Factories Ordinance, OSHAS series and BOI guidelines recognized as fire regulations and guidelines through current research findings. All respondents agreed to the inadequacy of detailed fire specific regulation for apparel sector Sri Lanka. And also, highly outdate version of Factories Ordinance in Sri Lanka highlighted in the current study. Therefore, apparel organizations have developed their own policies for fire safety by considering related local regulations and customers' requirements and guidelines. Accordingly, Walt Disney Company-International Labour Standards, Calvin Klein's guidelines, NIKE guidelines for occupational health and safety, and fire safety policy added as other fire related guidelines refer in the selected organizations in the study.

Xiuyu et al. (2012) asserted the failure to consider the factors contribute to building fire incidents lead to under-performance of present fire system in buildings. According to the literature findings twenty-three (23) factors recognized and these factors evaluated and ranked based on the relevancy to apparel sector in Sri Lanka. Faulty

wiring, welding work with electrical sparks, accumulation of waste fabric materials, garbage and papers, locations of firefighting services in Sri Lanka, building features/ materials which contributed to the speed fire development and fire spread, and lack of quick response of fire brigade recognized as six most relevant factors for fires in apparel buildings Sri Lanka. Wong and Lau (2007) acknowledged the faulty wiring and welding work with electrical sparks as a critical cause which commonly trigger the building fires based on the study in Hong Kong context. Further, lack of quick response of fire brigade also pointed out as a reason for recent fire event happened in Kandy, Sri Lanka (Daily News, 2019). In addition to those found from literature, twenty-six (26) factors which contribute to fire incidents newly recognised through interviews. Deficiencies of commanding at fire scene, high cost in installation and maintenance of fire safety system, high heat generating machines, and improper chemical storages, lack of safety culture and safety attitudes, and lack of specific fire regulations for apparel sector Sri Lanka highlighted some of the newly identified factors. Accordingly, altogether forty-nine (49) factors which contribute to apparel building fires in Sri Lanka recognised through the current study.

Moreover, current study recommended various strategies to overcome the identified forty-nine (49) factors which contribute to fire incidents in apparel sector Sri Lanka. Faulty wiring can be corrected by involving certified and competent electricians, conducting 'Megar' testing at least once in three years and avoiding wiring connections by electrical taps rather than a wire nut or other sanctioned connector. Introduce hot work permits and install flash-back arrestors pointed out as solutions to mitigate the risk in welding machines. Further, careless smoking factor can be alleviated through 'no smoking' policy.

Relevant impacts that can result due to fire incidents in apparel sector Sri Lanka gathered through current study. Fatalities, property damages and structure collapses elaborated as direct impacts by respondents. Moreover, challenges in disposing fire damages waste materials, decrease comfortability in the building or quality of life, decrease employees' bond and trust, environmental damages, increase expenses, insecurity in the employment, interruptions to building operation, and service interruption to third parties who use factory's by products to their business emphasised

as indirect impacts. Especially, findings of the present study have supported to identify opportunities create for new learning and modifications as a positive impact.

4.4.2 Refurbishment of Fire Damage Apparel Buildings in Sri Lanka

According to the above impacts, to recover from property damages, structural collapses, decrease building strength, and decreases in comfortability in the building, refurbishment has to perform as an initiative to reinstate the building condition as well as to improve the quality of life within the building.

A definition for the terminology, "refurbishment", was generated and it was encapsulated that refurbishment covers modifications, improvements, upgrades, updates, retrofits and renovation of the existing building to provide better building performance and environment to building occupants while focussed on building structural elements, building services and building aesthetics. This corroborated the interpretations of Ishak, Ibrahim, and Azizan (2018); Rahmat and Ali (2010) and Riley & Cotgrave (2011).

Reasons for undertaking refurbishment activities in apparel sector Sri Lanka expressed in the current research. It was evident that refurbishment activities in apparel sector Sri Lanka are much higher, because of the fact that apparel sector is one of the significant supporter in Sri Lankan economy with steady growth over the past ten years. In order to achieve the rapid development, apparel sector has to provide sophisticated solutions to complicated global requirements, involving creativity and experience in innovation and R&D which lead to undertake refurbishments. According to Arain (2005), pleasure, corrective, space altering, optimising and opportunity are the categories of reasons to perform a refurbishment activity. Moreover, to recover building damages and collapses due to an incident, to starts new production lines for novel design requirements, to enhance aesthetic appearance, to maintain requirements of customers (main buyers), to fulfil legal requirements and policy needs, and correct existing design or structural errors elaborated as reasons for undertaking refurbishment activity which were pointed out by two or more respondents in the current study. In addition, to fulfil sustainability requirements, to improve building condition, to improve building functionality, to compete with rival apparel companies, and to cater

planning forecasts also presented as reasons for refurbishment activities in apparel sector Sri Lanka. Accordingly, opinions of the respondents prove that there are many motives to trigger refurbishment choice and among that 'to recover building damages and collapses due to an incident' can be highlighted as reason which expressed because of the experienced in three past fire incidents.

Several participants are involved in refurbishment projects in order to gain multi-disciplinary skills and competencies to fulfil purpose of the refurbishment initiative. The success of the refurbishment project is depend on better synchronise between the multi-disciplinary project team. In line with past studies, this study recognised client, contractor, project manager, sub-contractor, building occupants, facility manager, FPE, other engineers, architects, quantity surveyors, safety officer, financial institutes, suppliers and local authorities as participants involved in refurbishment project. Especially, involvement of FPE claimed as a key requirement for refurbishment projects which the building damaged due to fire incident. FPE is needed to identify key evidences and root causes for fire and to advice accordingly to refurbishment team to minimise future threats to the building.

According to Gomes et al (2014) refurbishment is occurred at the use stage of the building life cycle. Refurbishment need to be perform in order to maintain the building and sustain its value because building is physically deteriorated over time (Chan, 2014). Being unique from new construction projects, activities of fire damaged refurbishment projects are complex and it is difficult to identify the sequence because of the nature of the incident and the condition of the building. Stages in fire damaged refurbishment project also same as general refurbishment activity and construction project, such as refurbishment need identification, design stage, tendering and selecting suitable contractor for undertake refurbishment activity. Apart from that, six activities recognised as special activities which performed in fire damaged refurbishment project. Activities are namely, preliminary survey, detailed visual investigation, isolate unsafe and hazardous areas, smoke and soot removal, deconstruction and perform refurbishment, and closure of refurbishment project.

Lund, Haddadi, Lohne & Bjorberg (2016) have stated that refurbishment projects are contacted with different challenges which should overcome by building owners and other interested parties. The present study evaluate sixteen (16) challenges of fire damaged refurbishment projects which recognised through literature review. According to the data analysis, all the challenges which identified through literature are applicable to apparel sector in Sri Lankan context. Absence of a proper site survey to investigate existing conditions of the building, impact of noise, vibration, dirt and fume, and unanticipated time overruns highlighted as challenges which gained strong agreement from all the respondents. Babangida (2014), CIRIA (1994) and Arain (2005) elaborated these three challenges respectively in their studies. In addition to those found from literature, eight (8) challenges newly recognised through interviews. Newly identified challenges are namely, difficulties in determine contingencies, disruptions to refurbishment activity due to simultaneous organisational operations, disturbances to other organisational operations by refurbishment activity, lack of assessment criteria regarding building services and comfort conditions of previous building, lack of standardized mechanism or regulation to follow regarding building fitness prior to the building occupy, lack of qualified professionals especially for fire damaged refurbishment, security risk, the involvedness and uncertainty of work, and unavailability of proper place for secure material storage. Accordingly, altogether twenty-five (25) challenges of fire damaged refurbishment projects in apparel sector Sri Lanka recognised through literature review and interviews. By considering all these challenges it is evident that the lack of qualified professionals for fire damaged refurbishments, Insufficient information on original drawings and other functional information, lack of assessment criteria regarding building services and comfort conditions of previous building, and lack of standardised mechanism or regulations to follow related to building fitness in terms of structural fitness and fitness of occupancy requirements and comfort before occupy the building; directly as well as indirectly lead to challenge the better recital of building performance mandates.

Moreover, literature findings further strengthened the above issues in refurbishment projects. Buildings carryout evaluations to identify the critical problems in the building performance (Preiser, 1995). Post Occupancy Evaluation (POE) is one of the methods

used to evaluate the performance of a building after it has been built and occupied (Hansen & Leo, 2017). POE mainly focuses three broad areas; process, functional performance and technical performance (Blyth & Gilby, 2012). Under the functional performance, it assess the building performance mandates, life cycle cost, operational management and strategic values. However, the building performance evaluation has not become a mainstream yet or, indeed, a core activity in refurbished buildings (Sharpe, 2019).

4.4.3 Building Performance of Fire Damage Refurbished in Apparel Buildings in Sri Lanka

Providing comfort to the building occupants is the essence of a building (Celik, 2010). Nevertheless, shocking fire events will challenge the essence of the building performance. To reinstate the fire damage, building occupants perform building refurbishments but, this refurbishment projects critically ignore the evaluation of building performance which is a vital need in providing occupancy comfort after a fire incident (Sharpe, 2019). Therefore, it is essential to figure out aspects to enhance building performance of fire damage refurbished buildings in apparel sector.

According to Celik (2010) BPMs play a key role in facilitating comfort to the building occupants. Findings of the present study explained the importance of BPMs on apparel sector in Sri Lanka. All respondents of the study marked 'yes' by agreeing that all five BPMs is essential to apparel sector Sri Lanka and then respondents provided explanations for their choice. The apparel sector in Sri Lanka is a human intensive sector which required to fulfil adequate special requirements in order to facilitate their work and wellbeing in comfortable manner. SP is very much important in apparel sector in order to minimise the accidents and near misses, to maintain correct ergonomics conditions, to decide machine layouts, and to safely perform maintenance activities. Pheng, Ying and Hiong (2008) mentioned SP as a functional performance concept and main concern of the mandate is to evaluate ergonomics arrangement of a specific space to gain maximum satisfaction to the respective occupants. ASHRAE (1981) expressed that TP is essential to evaluate the occupants' satisfaction with the thermal environment. TP is affected occupants' sensation of warm or cool and humid or dry (Huang, Zhu, Quyang & Cao, 2012). Findings of the current study revealed that

TP is essential in apparel sector due to the usage of high heat emitting machines in the apparel sector, possibility for curling effects in fabric, and high energy cost in air-conditioning system. IAQP identified as a key consideration in apparel sector because of involvement of dusty fabric materials in the process, hazardous chemical usage and frequent machine breakdowns due to dust accumulation. Lai, Mui and Wong (2009) also ranked IAQP as one of the top environmental risks related to public health in United States Environmental Protection Agency's comparative risk study. According to the standard EN 12665, VP is known as visual well-being brought by the visual environment. VP of the building has a direct relationship between comfort as well as energy consumption of the building (Kruger & Zannin, 2004). Current study stated due to the sensitive work nature in the apparel sector, VP is important to perform their work in effective and efficient manner which ultimately produce large quality output. According to Navai and Veitch (2003) AP is well-defined as a condition of contentment with acoustic levels in the environment. On the other hand, noise is defined as unwanted sound that leads to annoyance in the living or working space (Low, Liu & Oh, 2008). This literature finding strengthened by research finding such as, acoustic environment is directly related with occupancy health condition and therefore it is essential to maintain good AP in the organisation. Moreover, apparel organisations use high noise generating machines namely, sewing machines, generators, boilers, chillers, etc. Workers expose to this sound throughout their working hours hence AP is essential in apparel sector which plays a significant role not only in physical health but also in mental well-being as claimed by respondents in current research.

Literature findings recognised ASHRAE standard as one of the main standard related to TP. Further, Fanger's PMV-PPD model for thermal comfort had integrated with ISO Standard 7730 by modifying several scientific consensuses (Fanger, 1982). This implication discusses about the steady-state energy balance on the human body and it directs to the prediction of thermal sensation as a function of internal temperature, humidity, air velocity and mean radiant temperature. According to ENV Guidelines which referred to IAQP, acceptable concentration of carbon dioxide is 1000 ppm for indoor space (Kinnear, 1986). When consider about VP, basic rules and guidelines for

VP are established under EN Standard 12464-1 in terms of rules for artificial lighting in indoor working area by considering glare issues (The National Standards Authority of Ireland, 2011). Current study involved to investigate the involvement of regulations and guidelines related to BPMs. Findings of the study emphasized that there is a need to preparing regulations regarding BPMs specially focused on apparel sector Sri Lanka. Factories Ordinance Sri Lanka pointed out as the main legal regulation in Sri Lanka related to BPMs of apparel sector. Nonetheless, findings revealed that Factories Ordinance mainly focus on fire safety in the building, therefore less focus can be seen in BPMs. But vague or general statements can be found regarding space requirement for one person, temperature, ventilation and lighting. Moreover, BOI guideline which further support to maintain BPMs under Section 2 and 4, but findings claimed that the insufficient detailed information regarding BPMs in the guideline. Therefore, apparel buildings follow various standard and guidelines to somehow maintain their building performance. Among that, ISO standard, ASHRAE standard, American Conference of Government Industrial Hygienists guidelines, Walt Disney International Labour Standard, Occupational Exposure Level Control Plan, and NIKE compliance tool recognised as standards and guidelines involved in cases of current research.

Moreover, current study demonstrated general practices of maintaining BPMs in fire damage refurbished apparel buildings in Sri Lanka. IET team in one case is acted as the main responsible party to maintain SP in the organisation. IET team basically investigates spatial arrangements, employee factor, material flow, machine maintenance requirements to obtain time reductions in the production process as well as to enhance total SP in the organisation. In addition, Lean Audits, 5S Audits, internal ergonomics surveys, and change management policy asserted as another monitoring mechanisms regarding SP. Conducting investigations for production flow to identify special deficiencies which lead minimise time waste, and near misses reporting system further explained in the current study as aspects related to SP in apparel sector. Occupancy Exposure Control Policy recognised as the main policy related to TP, VP, AP and IAQP in one selected case. This study opined nuisance respirable dust level and fugitive emission level are measured in selected cases. Nuisance respirable dust level is monitored annually by an accredited party and maintain 0.20 mg/m3 as the

Threshold Limit Value for respirable fabric dust. Moreover, volatile organic compound test is conducted annually in the areas of potentially high fugitive emission levels such as printing units, and dye houses. Lung function test is conducted annually for all employees exposed to high fugitive emission as a biometric testing method. Maintaining VP in apparel buildings identified under various activities such as measuring lux levels for specific locations (checking tables, needle point), increase the roof height to reduce shadow effects, use eye pleasing colours, and install of sky lighting, glass facades and solar tubes lights. Study recognised regular inspection and repair of any loose connections in machines, use sound insulated rooms for generator and boilers, provide hearing protections, conduct audiometric tests, and measure indoor and boundary noise levels can be involved to enhance AP of apparel organisations.

Hartkopf and Loftness (1999) and Kinner (1986) recognised several requirements for BPMs and named them as four limits of acceptability. Four types of requirements are physiological requirements, psychological requirements, sociological requirements, and economic requirements. Forty-eight (48) requirements recognised for SP in apparel sector. Literature supported to identify sixteen (16) requirements for TP and it strengthened by another twelve (12) requirements. Altogether seventeen (17) requirements emphasised under four acceptable limits for IAQP. Similarly, VP demonstrated with thirteen (13) requirements from literature study and seven (78) requirements from current research. Further, AP supported with seventeen (17) requirements for acceptability in apparel sector.

Current research pointed out forty-five (45) challenges encountered in maintaining BPMs of fire damage refurbished apparel cases. Frequent design changes of production floor, frequent pathways block during production, and recruitment conduct without considering on the available space are some of the challenges identified under SP. TP is challenged by evaporative cooling mechanism affects to product quality, humidity issues in printing section, employees complaints regarding their uniform, lack of having apparel sector specific regulations for TP, and high heat emitting machines. New materials which contain dusty compounds, difficulties in collect fine fabric particles in the operation, and toxic fumes can accumulated in walls, duct

systems illustrated as some challenges in IAQP. Moreover, frequent changes in machine layouts without considering lighting positions, high cost for testing and evaluation of damaged lighting system, and lack of having apparel sector specific regulations for VP pointed out as some challenges in VP. Distractions to some employees and to office area due to music broadcast by PA system, unnecessary noise generation due to improper AC duct design, unnecessary noise generation due to sewing machines, vibration in flat seam, straight knife cutting and other machines, and lack of having apparel sector specific regulations for AP elaborated as challenges in AP of apparel sector in Sri Lanka. Especially, current research findings demonstrated five contradictory situations in maintaining BPMs in apparel organisations. Furthermore, the study provided various strategies to overcome identified forty-six challenges in BPMs of fire damage apparel buildings. Finally, a framework was develop to enhance building performance beyond restoration.

4.5 Summary

This chapter presented the data collection through semi- structured interviews, data analysis and research discoveries in order to achieve the objectives of the study. This chapter initially focused on analysing the current status of fire risk and safety system in apparel buildings Sri Lanka. Thereby, nature of fire risk, early fire detection techniques, fire safety teams, regulations and guidelines, factors contribute to fire incidents, strategies to overcome the identified factors, and impacts of fire incidents in these projects were identified. According to the impacts, such as property damages or structural collapses, decrease building strength, and decreases in comfortability in the building; refurbishment has to perform as an initiative to reinstate the building condition as well as to improve the quality of life within the building. Therefore, then the research focused on apparel building refurbishment after fire incident. Accordingly, reasons for undertaking a refurbishment project, key participants, main activities, and challenges were expressed regarding refurbishment projects conducted due to fire incidents in apparel buildings. By considering challenges it was evident that the lack of qualified professionals for fire damage refurbishments, insufficient information on original drawings and other functional information, lack of assessment criteria regarding building services and comfort conditions of previous building, and

lack of standardised mechanism related to building fitness in terms of structural fitness and fitness of occupancy requirements and comfort before occupy the building; directly as well as indirectly lead to challenge the better recital of building performance mandates. Therefore finally the study concentrated on enhancing building performance of fire damage apparel buildings in Sri Lanka by evaluating the importance of BPMs, involvement of regulations and guidelines of BPMs, general practices, acceptable requirements, current challenges and strategies to overcome identified challenges. In brief, the Chapter 4 facilitates to accomplish the aim of the research along with research objectives.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATION

5.1 Introduction

The Chapter 4 explored and deliberated the findings of data collection. The Chapter 5 concludes the findings of the research. A summary of the research and conclusions gain from the research is presented. Further, the chapter emphasized the contribution made to knowledge and industry practitioners. Subsequently, recommendations and further research areas were identified to contribute to new research direction.

5.2 Overview of the Research

The research was conducted under concurrent nested mixed design approach and data were collected through interviews and questionnaire survey. Interviews were involved with eighteen (18) respondents in three different groups. Questionnaire survey was conducted among thirty-six (36) respondents. Outcomes of the interviews were evaluated using manual content analysis. The data captured through questionnaire survey were analysed using RII technique. The findings of research supported to enhance building performance of fire damage refurbished buildings in apparel manufacturing sector in Sri Lanka.

5.3 Key Research Findings through Revisiting Objectives

Subsequent sections are presented the conclusions of the research findings.

5.3.1 Objective 1: Study the extent of building fire risk and factors contribute to fire risk in apparel manufacturing sector

The present study revealed that even though buildings are long-lasting infrastructures, which usually designed to withstand over sixty years, durability and performance of the buildings are affected by fire incidents. Even there are plenty of active and passive fire safety measures available, fire resistant building is still a major challenge worldwide. Apparel sector in Sri Lanka is identified the largest and most diverse contributor to Sri Lankan economy. Apparel sector employs 15% of the country's workforce and one apparel manufacturing company has the second largest workforce in Sri Lanka. Moreover, due to the production nature, it holds high risk for fire incidents. This fire risk was confirmed by stating 83.4% of respondents as high fire

risk in apparel sector in Sri Lanka. High fabric storages, hazardous chemical usage and high heat emitting machine operations pointed out as conditions which create high fire risk in apparel sector Sri Lanka. To fight against high fire risk in apparel sector, better symbiosis between elements of fire detection, notification and suppression emphasised by the current research. Thermography survey which evaluates temperature elevation identified as the only advance early fire detection techniques practice in apparel building in Sri Lanka. Further, fire evacuation, fire-fighting and fire-rescue trainings recognised as supporting aspects in fire safety system. On the other hand, lack of practice on passive fire protection and unavailability of apparel sector specific fire regulation in Sri Lanka asserted as a practice which hinder the effective building protection against fire. This inadequacy of specific legal requirement and outdated condition of existing regulations are fulfilled by various customers' (buyers') requirements and they play a dominant role in every apparel building.

To safeguard the building from critical fire incidents, forty-nine factors highlighted and strategies to overcome the identified loopholes elaborated in the current study. The identified factors were ranked using RII technique. Accordingly, 'faulty wiring' was ranked with highest relevance followed by 'welding work with electrical sparks' with RII value of 0.9889 and 'accumulation of waste fabric materials, garbage, paper' was ranked third. 'Locations of fire-fighting services in Sri Lanka' and 'Building design features/ materials which contributed to the fire development and fire spread' are ranked as fourth and fifth relevant factors. On the other hand, 'lift shafts which its doors removed or opened due to refurbishment', 'wooded building structures', 'HVAC system', 'Lack of staff in fire bridges' and 'poor equipped fire brigade' were ranked least with RII values.

In addition to those found from literature, twenty-six (26) factors which contribute to fire incidents were newly recognised through interviews. 'Worn out electrical sockets and grounding issues' and 'high cost in installation and maintenance of fire safety system' and 'improper chemical storages' as another factor which contribute for fire incidents in apparel sector. Apart from that, 'penetration through fire rated barriers', 'deficiencies of commanding at fire scene', 'lack of fire training and awareness', 'lack of technical knowledge regarding fire safety', 'lack of professionalism in fire service

providers', 'inadequacy of fire service providers in Sri Lanka', and 'lack of competent and educated fire protection engineers in Sri Lanka' as contributing factors for fire incidents.

Apart from all these factors, loopholes in regulations and guidelines regarding fire safety also highlighted by many respondents. Lack of specific fire regulations for apparel sector Sri Lanka', 'less regulations regarding passive fire protection in apparel sector', and 'interpretation differences in various fire regulations, standards and guidelines' recognised through the study. Furthermore, respondents pointed out; 'inadequacy of proper monitoring mechanism for fire regulations and guidelines in Sri Lanka', 'vague definitions in fire regulations', and 'outdated factories ordinance' as issues in regulatory framework which related to fire safety in apparel sector Sri Lanka. Accordingly, altogether forty-nine (49) factors which contribute to apparel building fire incidents recognised through literature review and interviews.

5.3.2 Objective 2: Explore the importance of BPMs for refurbishment of fire affected buildings in apparel manufacturing sector

Built environment facilitates to accomplish functionality of the building as well as occupant comfort. BPMs play a vital role in fulfilling comfortable needs of building occupants. The current study identified that BPMs are essential to apparel sector in Sri Lanka. Apparel sector in Sri Lanka is a human intensive sector which required to fulfil adequate special requirements in order to facilitate their work and wellbeing in comfortable manner. TP recognised as an essential mandate because of usage of high heating machines, impact of poor TP on fabric quality, and high operation cost in air-conditioning system. There are more than two-thousand employees, work in production floors and due to this situation indoor air pollution can be higher which impacts to their health conditions if the IAQP is neglected. VP is essential because employees deal with sensitive works which required quality lighting conditions in order to produce garments in good quality while mitigating health issues. AP also recognised as an essential mandates because of the involvement of noise generating machines, usage of music broadcasting system, indoor and outdoor noise considerations.

5.3.3 Objective 3: Investigate the challenges of managing BPMS and strategies to restore the performance of fire damaged buildings in apparel manufacturing sector

Even though BPMs essential to apparel manufacturing sector, the better application of BPMs have been limited by many challenges in the business operation. The research identified forty-five (45) challenges encountered in maintaining BPMs of post fire refurbished apparel manufacturing buildings. These challenges recognised separately for five BPMs, in addition five additional challenges, which represent the contradictory situations in maintain BPMs also evaluated. Seven challenges (7) pointed out under SP. High cost for changes and maintaining spatial arrangement, frequent design changes of production floor, employees' reluctant to follow established spatial arrangements, frequent pathways block during production, mismatch between designed space and current operation, recruitment conduct without considering on the available space and lack of having apparel sector specific regulations for SP emphasised as challenges regarding SP. Thirteen (13) challenges related to TP also identified. Among that, humidity issues in printing section, employees' complaints regarding their uniform, complaints regarding air-conditioning levels in shift changing time, and high heat emitting machines were highlighted. IAQP is affected due to seven (7) challenges which identified through data collection, among that new materials which contain dusty compounds, difficulties in collect fine fabric particles in the operation and toxic fumes can accumulated in walls, duct systems were frequently discussed. Frequent changes in machine layouts without considering lighting positions, distracts due to sensor lightings, high cost for testing and evaluation of damaged lighting system and lack of having apparel sector specific regulations for VP were recognised as challenges under VP. Distractions to some employees and to office area due to music broadcast by PA system, unnecessary noise generation due to improper AC duct design, unnecessary noise generation due to sewing machines and vibration in flat seam, straight knife cutting and other machines were identified as some of challenges out of six (6) challenges in AP. In addition, main five contradictory situations also elaborated as challenges in maintaining BPMs in post-fire refurbished apparel buildings.

To overcome the identified challenges, various strategies investigated under each challenge of BPMs. Altogether seventy-seven (77) strategies pointed out in this research. Eleven (11) strategies recognised under SP, among that U shape, and dancing production modules to optimise space plus production and save cost, evaluate the available space of the organisation and analyse with the production requirement and evaluate the available space of the organisation and analyse with workforce factor were highlighted. Maintaining correct humidity levels, considering employees' suggestions regarding uniform or allow them to sew their own uniform while adhere to the standard with their preferable material, providing separate split air-conditionings without central air-conditioning to areas which only work for few hours (cutting section), using sandwich panels for roof, isolation and use low heat emitting or modified machines emphasised as strategies for challenges of TP.

Among thirteen (13) strategies of IAQP, mitigate the involvement of dusty fabrics, use in-built dust sucking modified machines, install special sucking tubes for fabric cuttings areas, install in-built fabric dust sucking system in modified cutting machines, complete building flush after fire incident, proper testing before occupy the building, purge whole building after fire and install filters for smoke and dust in duct systems are emphasised in the study. Moreover, challenges in VP can be eliminated by involving strategies such as; check correct positioning of lights after layout change, provide task lights for places which do not have adequate lighting, request to government enforce apparel sector specific VP regulations, developed internal detailed policy to cover VP requirements and get higher management support and financial support to buy relevant tools. Proper sound insulation for office areas, use low or required volume in PA system, schedule the broadcasting time, proper tightness and fixing in duct system and change the unnecessary turns, job rotation and educate employees about the importance of PPE were recognised as strategies under AP. Common contradictory issues can be eliminated by involving strategies namely; prioritising BPMs according to the importance, isolation, use sound barriers or absorbance, install high frequency cutting machines, pre plan tasks and use organic or zero discharge hazardous chemicals.

5.3.4 Objective 4: Develop a framework to enhance the performance of the post-fire apparel buildings beyond restoration

A framework was developed based on research findings in order to accomplish the aim of the research, which is to examine building performance of post-fire refurbished buildings in apparel manufacturing sector in Sri Lanka.

The framework development process was based on five main steps, namely; present key themes, identification of push factors, identification of pull factors, determine the inter-relationships and develop the framework for the study. Accordingly, the framework was developed based on three main themes in the research, such as; building fires in apparel manufacturing sector, refurbishment of fire damaged building and building performance of post-fire refurbished apparel building. Then, these three themes were involved to recognise 'Push Factors', 'Pull Factors' and inter-relationship between identified factors. Push factors refer to conditions or aspects which trigger or drive the key themes in the framework. Pull factors discuss about the conditions or aspects which prevent or block the key themes in the framework. Both push factors, and pull factors can be acknowledged as positive or negative merely based on the nature of theme. Fourth stage was determine relevant inter-relationships for the framework. Inter-relationship and flow of the framework were determined based on the identified themes, push factors and pull factors. This inter-relationships are useful for better understanding the whole pictorial view of the developed framework. Final stage was to develop framework for the study. By considering all above four stages, factors, conditions and relationships final framework was development. This framework is useful as an encapsulated tool for research findings and enhance the performance of the building beyond restoration

5.4 Limitations of the Study

The findings of this research are subjected certain limitations. The focus of the current research was confined to apparel refurbished buildings, because in the Sri Lankan context, the buildings, which have high possibility for fire incidents found from apparel sector. Accordingly, due to the time constraint, only three (03) case studies were conducted. In addition, international health crisis caused by the COVID-19

impacted on the data collection process and had to face various restrictions in the research period.

5.5 Contribution to the Knowledge

This research has given a vital contribution to the information and knowledge regarding building performance of fire damage refurbished buildings in apparel sector. The outcome of the study can be involved to enlighten the knowledge in following ways.

- Identification and understanding of the concepts of building fires, fire damage refurbishment, and BPMs.
- Evaluation of fire risk in apparel buildings and its direct and indirect impacts.
- Identification of reasons for undertaking refurbishment projects.
- Exploration the activities of fire damage refurbishment projects.
- Investigation of the importance of BPMs in apparel sector.
- Exploration of general practices of maintaining BPMs in apparel buildings.

5.6 Recommendations for Industry Practitioners

Research outcome will be favourable for professionals in the industry. The following are the recommendations for professionals gained through this study.

- Understanding factors contribute to fire incidents in apparel buildings.
- Introducing strategies to overcome the identified factors which contribute to fire incidents.
- Engaging key participants involved in fire refurbishment project.
- Understanding challenges of fire damaged refurbishment project.
- Assisting acceptable requirements of BPMs to apparel buildings.
- Incorporating strategies to overcome the identified challenges regarding BPMs in fire damaged apparel building.

5.7 Recommendations for Academic Research

The findings of the research explored new research directions that are worthy for the academic researchers for future researches that are listed below.

- Study fire resistant techniques and strategies for apparel buildings.

- Prepare guidelines regarding fire safety management and BPM specifically for apparel buildings.
- Evaluate the most important and relevant BPM for apparel buildings.
- Explore the integration mechanism of acceptable requirements of BPMs to apparel buildings.

5.8 Summary

There are numerous studies on building integrity of fire damaged buildings, whereas less studies on maintaining BPMs of fire damage buildings is evident. Hence, the current study has shed light on enhancing of BPMs to fire damaged buildings in apparel manufacturing sector in Sri Lanka. This chapter provided the contributions for the enhancement of knowledge from the research and by recommendations for industry practitioners and for academic research.

REFERENCES

ABCB. (2005). International fire engineering guidelines. Canberra: Australian Building Codes Board.

Abowitz, A., & Toole, T. (2010). Mixed Method Research: Fundamental Issues of Design Validity, and Reliability in Construction Research. *Journal of Construction Engineering and Management, 136*(1), 108-116. doi:10.1061/ ASCE CO.1943-7862.0000026

Abrahams, J., & Stollard, P. (2002). *Fire from first principles: a design guide to building fire safety* (3rd ed.). London: Routledge.

Ada, M., Yüzer, N., & Ayvaz, Y. (2019). Postfire Damage Assessment of a RC Factory Building. *Journal of Performance of Constructed Facilities*, *33*(5), 04019047. doi:10.1061/(asce)cf.1943-5509.0001319

Aguirre, B. E., Torres, M. R., Gill, K. B., & Lawrence Hotchkiss, H. (2011). Normative collective behavior in the Station Building fire. *Social Science Quarterly*, *92*(1), 100-118. doi:10.1111/j.1540-6237.2011.00759.x

AirNow. (2017). How smoke from fires can affect your health. Retrieved from https://airnow.gov/index.cfm?action=smoke.index

Alam, M. S., Selvanathan, E. A., Selvanathan, S., & Hossain, M. (2019). The apparel industry in the post-multifiber arrangement environment: A review. *Review of Development Economics*, *23*(1), 454–474. https://doi.org/10.1111/rode.12556

Ali, A. S., Kamaruzzaman, N. S., & Salleh, H. (2009). The characteristics of refurbishment projects in Malaysia. *Facilities*, *27*(1/2), 56-65. doi: 10.1108/02632770910923090

Alkhazaleh, A., & Duwairi, H. (2015). Analysis of mechanical system ventilation performance in an atrium by consolidated model of fire and smoke transport simulation. *International Journal of Heat and Technology*, *33*(3), 121-126. doi:10.18280/ijht.330318

Alm, O., Witterseh, T., Clausen, G., Toftum, J., & Fanger, P. O. (1999). The impact of human perception of simultaneous exposure to thermal load, low-frequency ventilation noise and indoor air pollution. In *The 8th International Conference on Indoor Air Quality and Climate* . London: Construction Research Communications.

Amaratunga, D., Baldry, D., Sarshar, M., & Newton, R. (2002). Quantitative and qualitative research in the built environment: application of "mixed" research approach. *Work Study, 51*(1), 17-31. doi:10.1108/00438020210415488

American Society of Heating Refrigerating and Air Conditioning Engineers. (1981). *ASHRAE standard 55-81: Thermal comfort conditions for human occupancy*. Retrieved from website: https://www.ashrae.org/technical-resources/bookstore/standard-55-thermal-environmental-conditions-for-human-occupancy

American Society of Heating, Refrigerating and Air- Conditioning Engineers. (2004). *ANSI/ASHRAE 55: Thermal environmental conditions for human occupancy*. NY: Atlanta, USA.

Annerel, E., & Taerwe, L. (2011). NDT methods for the assessment of concrete structures after fire exposure. *Nondestructive Testing of Materials and Structures*, 773-778. doi:10.1007/978-94-007-0723-8_110

Appelbaum, M., Cooper, H., Kline, R. B., Mayo-Wilson, E., Nezu, A. M., & Rao, S. M. (2018). Journal article reporting standards for quantitative research in psychology: The APA Publications and Communications Board task force report. *American Psychologist, 73*(1), 3-25. doi:10.1037/amp0000191

Aronoff, S., & Kaplan, A. G. (1995). *Total workplace performance: Rethinking the office environment*. NY: Wdl Publications.

Arrue, B., Ollero, A., & Matinez de Dios, J. (2000). An intelligent system for false alarm reduction in infrared forest-fire detection. *IEEE Intelligent Systems, 15*(3), 64-73. doi:10.1109/5254.846287

Ary, D., Jacobs, L. C., Irvine, C. K., & Walker, D. A. (2018). *Introduction to research in education*. United States of America: Cengage Learning.

Astolfi, A., & Pellerey, F. (2008). Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. *The Journal of the Acoustical Society of America*, *123*(1), 163-173. doi:10.1121/1.2816563

Azad, T. A., Hasan, I., Saha, M. K., Ahmmed, R., Moni, S. J., & Kabir, H. (2018). Risk of Fire Disaster: Consequences on Industry Sectors in Bangladesh. *International Journal of Energy and Sustainable Development*, *3*(3), 52–63. Retrieved from http://files.aiscience.org/journal/article/pdf/70620029.pdf

Babangida, I Olubodun, F and Kangwa, J (2014) Building refurbishment: Holistic evaluation of barriers and opportunities In: Smith, S D (Ed.), *28th Annual ARCOM Conference*, 3-5 September 2012, Edinburgh, UK, Association of Researchers in Construction Management, 1289-1298

Bailey, C., Burgess, I., & Plank, R. (1996). Analyses of the effects of cooling and fire spread on steel-framed buildings. *Fire Safety Journal*, *26*(4), 273-293. doi:10.1016/s0379-7112(96)00027-6

Bayer, C. W. (2001). Causes of indoor air quality problems in schools: summary of scientific research. doi:10.2172/777701

Beranek, L. L. (1989). Application of NCB noise criterion curves. *Noise Control Engineering Journal*, *33*(2), 45. doi:10.3397/1.2827742

Blyth, A., & Gilby, A. (2012). *Guide to Post Occupancy Evaluation*. Retrieved from https://alastairblyth.files.wordpress.com/2012/01/poebrochurefinal06.pdf

BRE Centre for Sustainable Products. (2010). *Sustainable refurbishment – how to better understand, measure and reduce the embodied impacts*. Retrieved from https://www.bre.co.uk/filelibrary/Briefing_papers/98660-Sustainable-Refurb-Briefing-Paper.pdf

British Standard 15643-1 (2010). *General framework*. Sustainability of construction works – assessment of buildings Part1.

British Standard Institute. (2007). *BS EN 15251:2007-Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics*.

Brushlinsky, N.N. Ahrens, M. Sokolov, S.V. and Wagner, P. (2017), "World fire statistics", CTIF, International Association of Fire and Rescue Services, No. 22, available at: www.ctif.org/sites/ default/files/ctif_report22_world_fire_statistics_2017.pdf (accessed 30 June 2019).

Bryner, N., Madrzykowski, D., & Grosshandler, W. (2007). Reconstruction the Station Nightclub fire-computer modeling of the fire growth and spread. In *International Interflam Conference*.

Bsen. (1995). *ISO 7730: Moderate thermal environments, determination of the PMV and PPD indices and specification of the conditions for thermal comfort*. NY.

Bukowski, R., & Séquin, C. (1997). Interactive simulation of fire in virtual building environments. *Proceedings of the 24th annual conference on Computer graphics and interactive techniques - SIGGRAPH '97*. doi:10.1145/258734.258757

Bulletin (2014), "World fire statistics", The Geneva Association, No. 29, available at: www. genevaassociation.org/research-topics/world-fire-statistics-bulletin-no-29 (accessed 30 June 2019).

Caia, G., Ventimiglia, F., & Maass, A. (2010). Container vs. dacha: The psychological effects of temporary housing characteristics on earthquake survivors. *Journal of environmental psychology*, *30*(1), 60-66.

Capon, D. S. (1983). Categories in architectural theory and design: derivation and precedent. *Design Studies*, *4*(4), 215-226. doi:10.1016/0142-694x(83)90056-x

Celik, T. (2010). Fast and efficient method for fire detection using image processing. *ETRI Journal*, *32*(6), 881-890. doi:10.4218/etrij.10.0109.0695

Central Bank of Sri Lanka. (2018). *National output, expenditure and income*. *Annual Report 2018*. https://doi.org/10.1063/1.2132316

Chang, C., & Huang, H. (2005). A water requirements estimation model for fire suppression: A study based on Integrated Uncertainty Analysis. *Fire Technology*, *41*(1), 5-24. doi:10.1007/s10694-005-4627-5

Cheng, L., Ueng, T., & Liu, C. (2001). Simulation of ventilation and fire in the underground facilities. *Fire Safety Journal*, *36*(6), 597-619. doi:10.1016/s0379-7112(01)00013-3

Choi, J. H., Aziz, A., & Loftness, V. (2009). Decision support for improving occupant environmental satisfaction in office buildings: The relationship between sub-set of IEQ satisfaction and overall environmental satisfaction. In *the 9th International Conference Healthy Buildings*. NY: Syracuse.

Chow, W. K. (2005). Building Fire Safety in the Far East. *Architectural Science Review*, *48*(4), 285-294. doi:10.3763/asre.2005.4836

Chow, W., & Zou, G. (2005). Correlation equations on fire-induced air flow rates through doorway derived by large eddy simulation. *Building and Environment*, *40*(7), 897-906. doi:10.1016/j.buildenv.2004.09.010

Clausen, G., Carrick, L., Fanger, P. O., Kim, S. W., Poulsen, T., & Rindel, J. H. (1993). A comparative study of discomfort caused by indoor air pollution, thermal load and noise. *Indoor Air*, *3*(4). Retrieved from DOI:10.1111/j.1600-0668.1993.00006.x

Clifton, G. C., & Feeney, M. J. (2004). Fire Engineering Application to Multi-Story Steel Structures. *Modern Steel Construction*, *44*(3), 59-66.

Colombo Municipal Council: Fire Service Department. (2017). *Mandatory structural fire protection and access requirements to be included in proposed building plans*. Retrieved from https://www.colombo.mc.gov.lk/downloads/Single-Window-Counter/Fire-Clearance-Certificate/Guidelines.pdf

Creswell, J. (2014). *Research design ; qualitative, quantitative, and mixed method approaches*. London, United Kingdom: SAGE Publications Ltd.

Daily News. (2019). Are we sitting on a time bomb with fire risk in buildings? Retrieved from http://www.dailynews.lk/2019/01/21/business/174840/are-we-sitting-time-bomb-fire-risk-buildings

Danielsson, C. B. (2019). Holistic office design. *Organizational Behaviour and the Physical Environment*, 37-63. doi:10.4324/9781315167237-3

Demir, G., Kablan, A., Avşar, Y., Alyüz, Ü., & Ökten, H. E. (2016). Railway noise pollution prevention in terms of regulations: Case study of Istanbul. *International Journal of Environmental Science and Development, 7*(3), 198-202. doi:10.7763/ijesd.2016.v7.767

Department of Community Medicine. (2016). *Report on situational analysis on occupational health and safety in Sri Lanka*. Retrieved from http://www.searo.who.int/srilanka/documents/situational_analysis_in_occupational_health_and_safety_in_sri_lanka.pdf

Di Bella, A., Fausti, P., Scamoni, F., & Secchi, S. (2012). Italian experiences on acoustic classification of buildings. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings*.

Ding, L., Drogemuller, R., Rosenman, M., Marchant, D., & Gero, J. (2006). Automating code checking for building designs-DesignCheck.

Disaster Management Centre, United Nations Development Programme in Sri Lanka, & United Nations Development Programme Regional Centre. (2012). *Sri Lanka national report on disaster risk, poverty and human development relationship*. Retrieved from https://www.preventionweb.net/english/hyogo/gar/background-papers/documents/Chap3/Asia-overview/Sri-Lanka-DRAFT-march-09.pdfnd-papers/documents/Chap3/Asia-overview/Sri-Lanka-DRAFT-march-09.pdf

Douglas, J. (1996). Building performance and its relevance to facilities management. *Facilities, 14*(3/4), 23-32. doi:10.1108/02632779610112508

East Asia Pacific. (2013). 8 killed in Bangladesh garment factory fire. Retrieved from https://www.voanews.com/east-asia-pacific/8-killed-bangladesh-garment-factory-fire

East Asia Pacific. (2016). Fire at India garment factory kills at least 13 workers. Retrieved from https://www.voanews.com/east-asia/fire-india-garment-factory-kills-least-13-workers

EffectiveSOFTWARE. (2017, May 30). *Learning from history: A lesson in fire safety*. Retrieved from https://www.effective-software.com/blog/learning-from-history-a-lesson-in-fire-safety

Egbu, C., Young, B. and Torrance, V. (2002). Refurbishment management practices in the shipping and construction industries — lessons to be learned. *Building Research & Information*, 24(6), pp.329-338.

Export Development Board (EDB). (2012). *Industry capability report of export development board*.

Export Development Board. (2014). *Industry capability report*. Retrieved from https://www.srilankabusiness.com/pdf/industry_capability_reports/apparel-2017.pdf

Fanger, P. O. (1982). *Thermal comfort: Analysis and applications in environmental engineering*.

Félix, D., Monteiro, D., Branco, J. M., Bologna, R., & Feio, A. (2014). The role of temporary accommodation buildings for post-disaster housing reconstruction. *Journal of Housing and the Built Environment*, *30*(4), 683-699. doi:10.1007/s10901-014-9431-4

Fellows, R & Liu, A. (2003). *Research Methods for Construction*. 2nd ed. London: Blackwell Science Ltd.

Frontczak, M., & Wargocki, P. (2011). Literature survey on how different factors influence human comfort in indoor environments. *Building and Environment*, *46*(4), 922-937. doi:10.1016/j.buildenv.2010.10.021

Gane, V., & Haymaker, J. (2010). Benchmarking current conceptual high-rise design processes. *Journal of Architectural Engineering*, *16*(3), 100-111. doi:10.1061/(asce)ae.1943-5568.0000017

Garcia, M. M., Ahmed, A., & Mcgough, D. (2017). Non-invasive approaches for low energy retrofit of buildings: Implemetation, monitoring and simulation in a living lab case study. *Structural Studies, Repairs and Maintenance of Heritage Architecture XV*, *171*, 183–192. https://doi.org/10.2495/STR170161

Gillott, M., & Spataru, C. (2010). Materials for energy efficiency and thermal comfort in buildings.

Gomes, V., Saade, M., Lima, B., Mininel, L., & Silva, M. (2014). Life beyond operational stage: Exploring lifecycle zero energy definitions. In *The 17th Rinker International Conference*. Gainesville, FL.

Greenwood, D., Lockley, S., Malsane, S., & Matthews, J. (2010). Automated compliance checking using building information models. In *Proceedings of the Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors Held on 2-3 September 2010 in Paris, France*.

Grosshandler, W., Bryner, N. D., & Madrzykowski, K. K. (2005). *Report of the technical investigation of the Station Nightclub fire,. .* Washington, DC.

Hadjisophocleous, G. V., Benichou, N., & Tamim, A. S. (1998). Literature review of performance-based fire codes and design environment. *Journal of Fire Protection Engineering*, *9*(1), 12-40. doi:10.1177/104239159800900102

Hajibabai, L., Delavar, M. R., Malek, M. R., & Frank, A. U. (2006). Spatial cognition and wayfinding strategy during building fire. *Cognitive Processing*. doi:10.1007/s10339-006-0060-z

Halliday, J., & Booth, R. (2018, September 21). 'We're sitting on a timebomb': tower block residents on life after Grenfell. Retrieved from https://www.theguardian.com/uk-news/2018/mar/16/sitting-on-a-timebomb-tower-block-residents-on-life-after-grenfell

Halwatura, R., & Jayasinghe, M. (2008). Thermal performance of insulated roof slabs in tropical climates. *Energy and Buildings*, *40*(7), 1153-1160. doi:10.1016/j.enbuild.2007.10.006

Han, D., & Lee, B. (2009). Flame and smoke detection method for early real-time detection of a tunnel fire. *Fire Safety Journal*, *44*(7), 951-961. doi:10.1016/j.firesaf.2009.05.007

Hansen, P., & Leo, J. (2017). *Aspiring for added value with energy efficient building renovation*. Mälardalen University. Retrieved from http://www.diva-portal.org/smash/get/diva2:1113770/FULLTEXT01.pdf

Hartkopf, V., & Loftness, V. (1999). Global relevance of total building performance. *Automation in Construction*, *8*(4), 377-393. doi:10.1016/s0926-5805(98)00085-5

Hashim, A., Aksah, H. and Said, S. (2012). Functional Assessment through Post Occupancy Review on Refurbished Historical Public Building in Kuala Lumpur. *Procedia - Social and Behavioral Sciences*, 68, pp.330-340.

Hasofer, A. M., Beck, V. R., & Bennetts, I. D. (2011). *Risk analysis in building fire safety engineering* (2nd ed.). New York: Routledge.

Health and Safety Executive. (2019). The six basic factors. Retrieved from https://www.hse.gov.uk/temperature/thermal/factors.htm

Hong, T., Yan, D., D'Oca, S., & Chen, C. (2017). Ten questions concerning occupant behavior in buildings: The big picture. Building and Environment, 114, 518-530. doi:10.1016/j.buildenv.2016.12.006

Huang, L., Zhu, Y., Ouyang, Q., & Cao, B. (2012). A study on the effects of thermal, luminous, and acoustic environments on indoor environmental comfort in offices. *Building and Environment*, *49*, 304-309. doi:10.1016/j.buildenv.2011.07.022

Hui, P. S., Wong, L. T., & Mui, K. W. (2007). An Epistemic Indoor Air Quality Assessment Protocol for Air-Conditioned Offices. *Indoor and Built Environment*, 16(2), 139–147. doi:10.1177/1420326x07076503

Humphreys, M. A. (2005). Quantifying occupant comfort: are combined indices of the indoor environment practicable? *Building Research & Information*, *33*(4), 317-325. doi:10.1080/09613210500161950

Hutton, T. (2019). After the fire. Retrieved from https://www.buildingconservation.com/articles/fire-damage/fire-damage.htm

Inkeles, G. (2010). *Ergonomic living: How to create a user-friendly home & officer*. New York, NY: Simon & Schuster.

International Association of Fire and Rescue Services. (2018, January 11). *CTIF report-world fire statistics*. Retrieved from https://www.ctif.org/sites/default/files/2018-06/CTIF_Report23_World_Fire_Statistics_2018_vs_2_0.pdf

International Commission on Illumination. (2018). *Guide on interior lighting*. Retrieved from http://cie.co.at/publications/guide-interior-lighting

International Labour Organization. (1996). Globalization changes the face of textile, clothing and footwear industries. Retrieved from https://www.ilo.org/global/about-the-ilo/newsroom/news/WCMS_008075/lang--en/index.htm

International Labour Organization. (2011). Conditions required for visual comfort. Retrieved from https://www.iloencyclopaedia.org/part-vi-16255/lighting/item/284-conditions-required-for-visual-comfort

International Organization for Standardisation. (1983). *ISO standard 7730: Moderate thermal environments*.

Ishak, N., Ibrahim, F. A., & Azizan, M. A. (2018). Analysis of Factors Influencing Building Refurbishment Project Performance. *E3S Web of Conferences*, *34*, 1–7. https://doi.org/10.1051/e3sconf/20183401013

Islam, S., & Roman, R. I. (2019). Assessment of fire hazard on the readymade garment industry in Chittagong city, Bangladesh. *Indonesian Journal of Environmental Management and Sustainability*, *3*(1), 20–28. https://doi.org/https://doi.org/10.26554/ijems.2019.3.4.20-28

Jha, A., Zaidi, Z., Ramaswamy, S., Gupta, A., & Shama, B. (2017). *FICCI – Pinkerton India risk survey*. Retrieved from http://www.ficci.in/pressrelease/2806/india-risk-survey-ficci-press-release.pdf

John, T. (2017, June 23). *The continuing urgency of the Grenfell Tower Inferno*. Retrieved from https://time.com/4830302/grenfell-tower-london-fire/

Jonas, J. M. (2017). Research design. In *Stakeholder integration in service innovation* (pp. 17-23). Retrieved from https://doi.org/10.1007/978-3-658-19463-5_2

Kale, A., & Kale, A. (2009). Basics of research methodology. *Essentials of Research Methodology and Dissertation Writing*, 7-7. doi:10.5005/jp/books/10297_2

Kim, J. O., Traore, M. K., & Warfield, C. (2010). The textile and apparel industry in developing countries. *Textile Progress*, *38*(3), 1–64. https://doi.org/https://doi.org/10.1533/tepr.2006.0003

Kinnear, R. G. (1986). Investigation of fire-damaged buildings. *Structural Survey*, *4*(1), 31-34. doi:10.1108/eb006225

Kline, R. B. (2004). Beyond significance testing: Reforming data analysis methods in behavioral research. doi:10.1037/10693-000

Kobes, M., Helsloot, I., De Vries, B., & Post, J. G. (2010). Building safety and human behaviour in fire: A literature review. *Fire Safety Journal*, *45*(1), 1-11. doi:10.1016/j.firesaf.2009.08.005

Kodur, V., Kumar, P., & Rafi, M. (2019). Fire hazard in buildings: Review, assessment and strategies for improving fire safety. *PSU Research Review*. https://doi.org/https://doi.org/10.1108/PRR-12-2018-0033

Krüger, E. L., & Zannin, P. H. (2004). Acoustic, thermal and luminous comfort in classrooms. *Building and Environment*, *39*(9), 1055-1063. doi:10.1016/j.buildenv.2004.01.030

Kuligowski E.D. (2016) Human Behavior in Fire. In: Hurley M.J. et al. (eds) SFPE Handbook of Fire Protection Engineering. Springer, New York, NY

Kumara, R. (2011). *Research methodology* (2nd ed.). Dorling Kindersley (India) Pvt Ltd.

Lai, A., Mui, K., Wong, L., & Law, L. (2009). An evaluation model for indoor environmental quality (IEQ) acceptance in residential buildings. *Energy and Buildings*, *41*(9), 930-936. doi:10.1016/j.enbuild.2009.03.016

Lai, J. H., & Yik, F. W. (2007). Perceived importance of the quality of the indoor environment in commercial buildings. *Indoor and Built Environment*, *16*(4), 311-321. doi:10.1177/1420326x07080463

Lai, J. H., & Yik, F. W. (2009). Perception of importance and performance of the indoor environmental quality of high-rise residential buildings. *Building and Environment*, *44*(2), 352-360. doi:10.1016/j.buildenv.2008.03.013

Lanier Pence, P., Phillips Carson, P., Carson, K. D., Hamilton, J. B., & Birkenmeier, B. (2003). And all who jumped died: the Triangle Shirtwaist factory fire. *Management Decision*, *41*(4), 407-421. doi:10.1108/00251740310468135

Le, A. T. H., Park, K. S., Domingo, N., Rasheed, E., & Mithraratne, N. (2018). Sustainable refurbishment for school buildings: a literature review. *International Journal of Building Pathology and Adaptation*.

Li, Y., Xu, F., & Li, X. (2016). Intelligent systems for managing returns in apparel supply chains. In *Information Systems for the Fashion and Apparel Industry* (pp. 199–219). Woodhead Publishing Series in Textiles. https://doi.org/https://doi.org/10.1016/B978-0-08-100571-2.00010-5

Li, J., Zlatanova, S., & Fabbri, A. (2007). *Geomatics solutions for disaster management*. Berlin, Germany: Springer Science & Business Media.

Lidwell, W., Holden, K., & Butler, J. (2010). *Universal principles of design, revised and updated: 125 ways to enhance usability, influence perception, increase*

appeal, make better design decisions, and teach through design. Rockport Pub.

Lin, C., Wang, S., Hung, C., & Hsu, J. (2006). Ventilation effect on fire smoke transport in a townhouse building. *Heat Transfer—Asian Research*, *35*(6), 387-401. doi:10.1002/htj.20127

Liu, X., Zhang, H., & Zhu, Q. (2012). Factor analysis of high-rise building fires reasons and fire protection measures. *Procedia Engineering*, *45*, 643-648. doi:10.1016/j.proeng.2012.08.216

Lottman, B., Koenders, E., Blom, C., & Walraven, J. (2013). Spalling of concrete due to fire exposure: A coupled fracture mechanics and pore pressure approach. *MATEC Web of Conferences*, *6*, 05002. doi:10.1051/matecconf/20130605002

Maraveas, C., Fasoulakis, Z., & Tsavdaridis, K. D. (2017). Post-fire assessment and reinstatement of steel structures. *Journal of Structural Fire Engineering*, *8*(2), 181-201. doi:10.1108/jsfe-03-2017-0028

Mbamali, I., Aiyetan, O., & Kehinde, J. (2005). Building design for buildability: An investigation of the current practice in Nigeria. *Building and Environment*, *40*(9), 1267-1274. doi:10.1016/j.buildenv.2004.10.006

McClure, K. (2018, July 12). 7 of the world's deadliest manufacturing disasters in the last 20 years. Retrieved from https://www.sourcify.com/7-of-the-worlds-deadliest-manufacturing-disasters-in-the-last-20-years/

McGrattan, K. B. (2004). *Fire dynamics simulator: Technical reference guide*. Gaithersburg, MJ.

Mizanuzzaman, M. (2016). Loss and damage assessment in the context of fire hazards: A study on selected garment factories in Bangladesh. *International Journal of Finance and Banking Research*, *2*(2), 24–39. https://doi.org/10.11648/j.ijfbr.20160202.11

Mohataz Hossain, M., & Shabbir Ahmed, K. (2013). Illumination conditions and visual comfort in production spaces of ready-made garments factories in

Dhaka. *International Journal of Engineering and Technology*, *5*(5), 587–592. https://doi.org/10.7763/ijet.2013.v5.623

Mora, R., Bitsuamlak, G., & Horvat, M. (2011). Integrated life-cycle design of building enclosures. *Building and Environment*, *46*(7), 1469-1479. doi:10.1016/j.buildenv.2011.01.018

Moriarty, R. (2019, September 20). *Electrical fire reported at Crowne Plaza Hotel*. Retrieved from https://www.syracuse.com/crime/2019/09/electrical-fire-reported-at-crowne-plaza-hotel-in-syracuse-firefighters-say.html

MTV Channel Pivate Ltd. (2015). Police launch investigations into Ratmalana factory fire. Retrieved from https://www.newsfirst.lk/2015/08/09/police-launch-investigations-into-ratmalana-factory-fire/

MTV Channel Private Ltd. (2015). Fire breaks out in Wattala garment factory. Retrieved from https://www.newsfirst.lk/2015/06/07/fire-breaks-out-in-wattala-garment-factory/

MTV Channel Private Ltd. (2019). Major fire breaks out in garment factory at Pannala. Retrieved from https://www.newsfirst.lk/2019/06/14/major-fire-breaks-out-in-garment-factory-at-pannala/

Mukherji, P., & Albon, D. (2018). *Research methods in early childhood: An introductory guide* (3rd ed.). London: SAGE Publications Ltd.

Nabil, A., & Mardaljevic, J. (2006). Useful daylight illuminances: A replacement for daylight factors. *Energy and Buildings*, *38*(7), 905-913. doi:10.1016/j.enbuild.2006.03.013

Nandasena, Y. L. S., Wickremasinghe, A. R., & Sathiakumar, N. (2010). Air pollution and health in Sri Lanka: a review of epidemiologic studies. *BMC public health*, *10*(1), 300.

National Academies of Sciences, Engineering, and Medicine. (2009). Communicating the Value of Research: Contractor's Final Report. Washington, DC: The National Academies Press. https://doi.org/10.17226/23034.

National Fire Protection Association. (2019). *List of NFPA codes and standards*. Retrieved from https://www.nfpa.org/Codes-and-Standards/All-Codes-and-Standards/List-of-Codes-and-Standards

Navai, M., & Veitch, J. A. (2003). *Acoustic satisfaction in open-plan offices: review and recommendations*. Retrieved from http://www.nrc-cnrc.gc.ca/obj/irc/doc/pubs/rr/rr151/rr151.pdf

Nayak, R., & Padhye, R. (2015). Global scenario of apparel manufacturing. https://doi.org/https://doi.org/10.1016/B978-1-78242-232-7.00001-1

Nazaroff, W. W. (2013). Four principles for achieving good indoor air quality. *Indoor Air*, *23*(5), 353-356. doi:10.1111/ina.12062

News1st. (2019). Fire accident archives. Retrieved from https://www.newsfirst.lk/tag/fire-accident/

Noshuhaila. (2013, September 2). *Led Lighting (CIBSE code for interior lighting)* [Video file]. Retrieved from https://www.slideshare.net/nosuhaila/led-lighting-code-for-interior-lighting-1994

Olesen, B. W., MORENO-BELTRÕN, D. L. M.-B., RIOS, M., TÄHTI, E., NIEMELÄ, R., LANDER, L., & HAGSTRÖM, K. (2001). Target values for acceptable thermal environments for comfort. In *Industrial Ventilation Design Guidebook* (pp. 355–413). https://doi.org/https://doi.org/10.1016/B978-012289676-7/50009-6

Oral, G. K., Yener, A. K., & Bayazit, N. T. (2004). Building envelope design with the objective to ensure thermal, visual and acoustic comfort conditions. *Building and Environment*, *39*(3), 281-287. doi:10.1016/s0360-1323(03)00141-0

Ouellette, M. (1993). This way out. *Progressive Architecture*, *74*(7), 39-42.

Oyedele, L. O., Tham, K. W., Fadeyi, M. O., & Jaiyeoba, B. E. (2012). Total building performance approach in building evaluation: Case study of an office building in Singapore. *Journal of Energy Engineering*, *138*(1), 25–30. https://doi.org/10.1061/(ASCE)EY.1943-7897.0000056

Panditharathene, K. P. (2000). *Urban space and meaning; a correlation with special reference to Sri Lanka* (Master's thesis, University of Moratuwa, Moratuwa, Sri Lanka). Retrieved from http://dl.lib.mrt.ac.lk/bitstream/handle/123/1106/pre-text.pdf?sequence=4&isAllowed=y

Papadonikolaki, E., Verbraeck, A., & Wamelink, H. (2017). Formal and informal relations within BIM-enabled supply chain partnerships. *Construction Management and Economics*, *35*(8–9), 531–552.

Park, H., Meacham, B. J., Dembsey, N. A., & Goulthorpe, M. (2014). Enhancing building fire safety performance by reducing miscommunication and misconceptions. Fire technology, 50(2), 183-203.

Paul Davis Corporation. (2014). Fire damage repair process. Retrieved from https://pauldavis.com/fire-damage-repair-process/

Peters, R. J. (2013). *Acoustics and noise control*. London, England: Routledge.

Pheng Low, S., Ying Liu, J., & Hiong Oh, K. (2008). Influence of total building performance, spatial and acoustic concepts on buildability scores of facilities. *Facilities*, *26*(1/2), 85-104. doi:10.1108/02632770810840327

Polonsky, M. J., & Waller, D. S. (2015). *Designing and managing a research project: A business student's guide*. Thousand Oaks, Calif: Sage Publications.

Preiser, W. F. E. (1995). Post-occupancy evaluation: How to make buildings work better. *Facilities*, *13*(11), 19–28. https://doi.org//10.1108/02632779510097787

Prentice, R., & Neve, G. De. (2017). Five years after deadly factory fire, Bangladesh's garment workers are still vulnerable. Retrieved November 24, 2017, from http://theconversation.com/five-years-after-deadly-factory-fire-bangladeshs-garment-workers-are-still-vulnerable-88027

Punch, K. F. (2006). Introduction to social research—Quantitative & qualitative approaches.*Forum: Qualitative Social Researach*, *7*(2). Retrieved from DOI: http://dx.doi.org/10.17169/fqs-7.2.109

Raaz, N. A. (2016). Safety problems and remedies in garments industry. Retrieved June 14, 2016, from http://textilemerchandising.com/safety-problems-and-remedies-in-garments-industry/

Real Estate & Mortgage Insights. (2018). Is it time to renovate or repair your home? Retrieved from https://www.realestateabc.com/insights/renovate-or-repair.html

Reichard, G., & Papamichael, K. (2005). Decision-making through performance simulation and code compliance from the early schematic phases of building design. *Automation in Construction*, *14*(2), 173-180.

Reinhart, C. F., & Walkenhorst, O. (2001). Validation of dynamic RADIANCE-based daylight simulations for a test office with external blinds. *Energy and Buildings*, *33*(7), 683-697. doi:10.1016/s0378-7788(01)00058-5

Reinhart, C. F., Mardaljevic, J., & Rogers, Z. (2006). Dynamic daylight performance metrics for sustainable building design. *LEUKOS*, *3*(1), 7-31. doi:10.1582/leukos.2006.03.01.001

Renz, S. M., Carrington, J. M., & Badger, T. A. (2018). Two strategies for qualitative content analysis: An intramethod approach to triangulation. *Qualitative Health Research*. Retrieved from https://doi.org/10.1177/1049732317753586

Riley, M., & Cotgrave, A. (2011). The technology of refurbishment and maintenance. In *Construction Technology 3*. New York. Palgrave Macmillan.

Rise, P. (2008). Restoring fire damaged buildings. Retrieved from http://www.buildmagazine.org.nz/assets/PDF/B104-60-FireDamage.pdf

River, E. (2014). Fire damaged building repair. Retrieved from https://www.lwm-info.org/470/42---Fire-Damaged-Building-Repair---Eagl

Rodgers, P. A., & Yee, J. (Eds.). (2015). *The Routledge companion to design reseach*. NY: Routledge.

Roger, Z. (2006). *Daylight metric development using daylight autonomy calculations in the sensor placement optimisation tool* . Colorado, USA: Boulder.

Ronayne Construction LTD. (2018). Refurbishment works. Retrieved from http://www.ronayne.co.nz/refurbishment-works

Rowley, J. (2014). Designing and using research questionnaires. *Management Research Review, 37*(3), 308-330. doi:10.1108/mrr-02-2013-0027

Sandelowski, M. (2000). Combining Qualitative and Quantitative Sampling , Data Collection , and Analysis Techniques in Mixed-Method Studies, 246–255.

Satti, H. M., & Krawczyk, R. J. (2004). Issues of integrating building codes. Symposium conducted at CAD ASCAAD International Conference, e-Design in Architecture.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Students* (5th ed.). Essex, England: Pearson Education Limited.

Science Learning Hub. (2007). What is fire? Retrieved from https://www.sciencelearn.org.nz/resources/747-what-is-fire

Sedex Information Exchange. (2013). *Fire safety briefing*. Retrieved from http://www.sedexglobal.com/member-services/reporting/

Shah Ali, A., Nizam Kamaruzzaman, S. and Salleh, H. (2009). The characteristics of refurbishment projects in Malaysia. *Facilities*, 27(1/2), pp.56-65.

Shakil, H. (2016). *Fire hazard, its consequences and possible preventions*. Jahangirnagar University. Retrieved from https://www.academia.edu/9848480/Fire_Hazard_Its_Consequences_and_Possible_Preventions

Sharpe, T. (2019). Mainstreaming building performance evaluation for the benefit of users. *Building Research & Information*, *47*(3), 251–254. https://doi.org/https://doi.org/10.1080/09613218.2019.1526470

Shoaib, S. (2012). Death toll from Karachi factory fire soars. Retrieved from https://www.bbc.com/news/world-asia-19566851

Shokouhi, M., Nasiriani, K., Khankeh, H., Fallahzadeh, H., & Khorasani-Zavareh, D. (2019). Exploring barriers and challenges in protecting residential fire-related injuries: a qualitative study. Journal of injury and violence research, 11(1), 81.

Sicurella, F., Evola, G., & Wurtz, E. (2012). A statistical approach for the evaluation of thermal and visual comfort in free-running buildings. *Energy and Buildings*, *47*, 402-410. doi:10.1016/j.enbuild.2011.12.013

Sime, J. (2001). An occupant response shelter escape time (ORSET) model. *Safety Science*, *38*(2), 109-125. doi:10.1016/s0925-7535(00)00062-x

Singh, S., & Khajuria, R. (2018). Penicillium enzymes for the textile industry. In *New and Future Developments in Microbial Biotechnology and Bioengineering* (pp. 201–215). https://doi.org/https://doi.org/10.1016/B978-0-444-63501-3.00011-9

Sui Pheng, L., Xiaopeng, D., & Li Ting, Q. (2012). Assimilating total building performance mandates with Chinese geomancy principles and scenarios. *Facilities*, *30*(13/14), 558-589.

Sustainabilty Report. (2017). *Sustainability report 2015-2017*. Retrieved from https://www.brandix.com/images/brandix-lanka-sustainability-report-2015-2017.pd

Symon, G., Cassell, C., & Johnson, P. (2016). Evaluative practices in qualitative management research: A critical review. *International Journal of Management Reviews*, *20*(1), 134-154. doi:10.1111/ijmr.12120

The Institute for Construction Training and Development. (2011). *Annual report*. Retrieved from Ministry of Construction, Engineering Services, Housing and Common Amenities website:

https://www.parliament.lk/uploads/documents/paperspresented/annual_report_institute_for_construction_training_and_development_2011.pdf

The National Institute for Occupational Safety and Health. (2013). Indoor Environmental Quality. Retrieved from https://www.cdc.gov/niosh/topics/indoorenv/default.html

The National Standards Authority of Ireland. (2011). *Light and lighting - Lighting of workplaces - Part 1: Indoor workplaces*. Retrieved from https://infostore.saiglobal.com/preview/98701186098.pdf?sku=861397_SAIG_NSAI_NSAI_2049330

Tongco, M. D. (2007). Purposive sampling as a tool for informant selection. *Ethnobotany Research and Applications, 5*, 147. doi:10.17348/era.5.0.147-158

Trade Economics. (2019). Sri Lanka GDP From Manufacturing | 2019 | Data | Chart | Calendar | Forecast. Retrieved September 5, 2019, from https://tradingeconomics.com/sri-lanka/gdp-from-manufacturing

Tubbs, J., & Meacham, B. (2007). *Egress design solutions: A guide to evacuation and crowd management planning*. Hoboken, NJ: John Wiley & Sons.

Urban Development Authority. (2018). *Part I: General regulations*. Retrieved from https://www.uda.gov.lk/attachments/devplan_detailed/for_public_comments/General%20Regulation-%20Report_2018.11.08.pdf

Utiskul, Y., Quintiere, J. G., Rangwala, A. S., Ringwelski, B. A., Wakatsuki, K., & Naruse, T. (2005). Compartment fire phenomena under limited ventilation. *Fire Safety Journal*, *40*(4), 367-390. doi:10.1016/j.firesaf.2005.02.002

Wadud, Z., & Huda, F. Y. (2016). Fire safety in the readymade garment sector in Bangladesh: Structural inadequacy versus management deficiency. *Fire Technology, 53*(2), 793-814. doi:10.1007/s10694-016-0599-x

Waidyasekara, K. G. A. S., Thilini, P. G. I. D., & Dahanayake, K. W. D. K. C. (2013). Investigate fire safety aspects of high rise buildings in Sri Lanka: strategies framework.

Waldman, D. A., & Spangler, W. D. (1989). Putting together the pieces: A closer look at the determinants of job performance. *Human Performance*, *2*(1), 29-59. doi:10.1207/s15327043hup0201_2

Wang, Y. C., Wald, F., Torok, A., & Hajpal, M. (2008). *Fire damaged structures*. Czech Technical University in Prague.

WBDG. (2012). *Design objectives: National Institute of Building Science*. Retrieved from http://www.wbdg.org/design/designobjectives.php

Wei, Y., Jie, L., Jun, F., & Yongming, Z. (2013). Color model and method for video fire flame and smoke detection using Fisher linear discriminant. *Optical Engineering*, *52*(2), 027205. doi:10.1117/1.oe.52.2.027205

Well, J. W. (2013). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. In *Research design Qualitative quantitative and mixed methods approaches*. https://doi.org/10.1007/s13398-014-0173-7.2

Wessels, P. W., & Basten, T. G. (2016). Design aspects of acoustic sensor networks for environmental noise monitoring. *Applied Acoustics*, *110*, 227-234. doi:10.1016/j.apacoust.2016.03.029

Wijerathne H.A.N. (2011). Preliminary study on sick building syndrome in office environment in Sri Lanka, Unpublished Dissertation. Department of Building Economics.

Wohlwill, J. F., & Weisman, G. D. (2012). *The Physical Environment and Behavior: An Annotated Bibliography and Guide to the Literature*. Berlin, Germany: Springer Science & Business Media.

Wong, L. T., & Lau, S. W. (2007). A fire safety evaluation system for prioritizing fire improvements in old high-rise buildings in Hong Kong. *Fire Technology*, *43*(3), 233-249. doi:10.1007/s10694-007-0014-8

Wong, L., Mui, K., & Hui, P. (2008). A multivariate-logistic model for acceptance of indoor environmental quality (IEQ) in offices. *Building and Environment*, *43*(1), 1-6. doi:10.1016/j.buildenv.2007.01.001

Wong, N. H., & Jan, W. L. (2003). Total building performance evaluation of academic institution in Singapore. *Building and Environment*, *38*(1), 161-176. doi:10.1016/s0360-1323(02)00021-5

Yadav, A. (2019, February 14). Delhi fire department reeling under lack of staff, equipment, India Today. Retrieved from https://www.indiatoday.in/mail-today/story/delhi-fire-department-reeling-under-lack-of-staff-equipment-1455640-2019-02-1

Yin, R.K. (2009). *Case study research: design and methods* (4th edi). London: SAGE Publications.

Yin, R. K. (2011). *Qualitative research from start to finish*. NY: The Guilford Press.

Zhang, Y., Lin, K., Zhang, Q., & Di, H. (2006). Ideal thermophysical properties for free-cooling (or heating) buildings with constant thermal physical property material. *Energy and Buildings*, *38*(10), 1164-1170. doi:10.1016/j.enbuild.2006.01.008

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Dear Sir/Madam,

Research Dissertation – Interview Guideline (M.Sc. (by Research)

I am a postgraduate student of University of Moratuwa, reading for Master of Science (by Research). I am conducting a research titled "Post Fire Refurbishment of Apparel Manufacturing Buildings for Enhanced Building Performance". This research is conducted under the supervision of Mr. Mahesh Abeynayake, and Dr Pournima Sridarran, Senior Lecturers at the Department of Building Economics.

I am conducting interviews for case studies focussing on apparel manufacturing buildings, which have conducted post-fire refurbishment activity. Below mentioned objectives are intended to be accomplished through these case studies.

1. Study the extent of building fire risk and factors contribute to fire risk in apparel manufacturing sector

2. Explore the importance of BPMs for refurbishment of fire affected buildings in apparel manufacturing sector

3. Investigate the challenges of managing BPMs and strategies to restore the performance of fire damaged buildings in apparel manufacturing sector

4. Develop a framework to enhance the performance of the post-fire apparel building beyond restoration

Kindly allow me an appointment to conduct the interviews. I assure that the information collected will be purely used for the research purpose, and the confidentiality of the details will be strictly maintained.

Thanking you,

R.M.D.I.M. Rathnayake
Postgraduate Student
Department of Building Economics
University of Moratuwa.
Tel: 071-6935979
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ANNEXURE I- INTERVIEW GUIDELINE A

Interview Guideline for Experts in Fire Safety/ Fire Risk Management

Section I- Details of the Respondent

1. Name (Optional): ……
2. Name of the organisation (Optional): …….
3. Designation: ……
4. Work experience: ……

Section II- Details of the fire safety and fire risk management

5. How you describe the fire risk in apparel industry SL

   …….
6. Why fire resistant building is still a major challenge worldwide?

   …….
7. Describe the fire safety/ fire risk management system in the organisation?

   …….
8. Any early fire detection systems or techniques practice?

   …….
9. Describe about the fire team formed in the organisation?

   …….
10. Please describe the importance or involvement of fire regulations or standards affecting for apparel industry

    …….
11. What are the practical issues or challenges in practice and regulations' requirements

    …….

12. Please provide the following information of the fire event happened (if any)

Details Category	Description
Date of the fire event	
Name of the location	
Describe the fire affected area (size/ environment etc.)	
Cost of the property damage	
Reasons	

13. Describe about the post fire activities in fire incident

……

14. What are the direct and indirect impacts of fire to the building

……

15. How this fire affected to BPM (Building Performance Mandates)

a. Spatial Performance

……

b. Thermal Performance

……

c. Indoor Air Quality Performance

……

d. Visual Performance

……

e. Acoustic Performance

……

16. What are the challenges or issues in fire safety system?

……

17. What are the solutions to overcome above mentioned challenges/ suggestions for have a better fire safety environment in apparel industry?

……

Thank you very much for the information given.

ANNEXURE II- INTERVIEW GUIDELINE B

Interview Guideline for Experts in Refurbishment Activities

Section I- Details of the Respondent

01. Name (Optional): …….
02. Name of the organisation (Optional): …….
03. Designation: …….
04. Work experience: …….

Section II- Details of the post fire refurbishment

05. In your opinion, what do you mean by "refurbishment"?

……..…….

06. Do you think that the refurbishment projects in Sri Lanka are higher in apparel buildings compared to others? If the answer is *yes*, please explain the reasons

……..…….

07. What are the general reasons for undertaking a refurbishment activity?

……..…….

08. Please provide the following information of the post fire refurbishment project

Details Category	Description
Total cost of the refurbishment :	
Scope of works :	
Planned duration of the project	
Duration of the Project:	
Remarks:	

09. How did you ensure/ will ensure **Visual Performance** during the refurbishment project?

……..…….

10. How did you ensure/ will ensure **Thermal Performance** during the refurbishment project?

    ……..…….

11. How did you ensure/ will ensure **Acoustic Performance** during the refurbishment project?

    ……..…….

12. How did you ensure/ will ensure **Indoor Air Quality Performance** during the refurbishment project?

    ……..…….

13. How did you ensure/ will ensure **Spatial Performance** during the refurbishment project?

    ……..…….

14. Who are the parties involved to post fire refurbishment activity?

    ……..…….

15. Did you adhere to any standard or systematic approach for conducting the refurbishment? If yes, please describe

    ……..…….

    If the answer is no, please explain the reasons for not adhering to any standard or systematic approach for conducting the refurbishment exercise

    ……..…….

16. What were the stages or the main activities of the refurbishment project that were identified for the project?

    ……

17. What were the impacts of the refurbishment exercise?

    ……

18. Please rate the below listed challenges in refurbishment project and provide any solutions. Please indicate your level of agreement regarding below challenges in post fire refurbishment by marking one of the five alternatives.

1	**2**	**3**	**4**	**5**
Strongly Disagree	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Strongly Agree**

	1	2	3	4	5	Solutions
Absence of a proper site survey to investigate existing conditions of the building						
The impact of noise, vibration, fumes and dirt						
Unanticipated time overruns						
Accumulation of salvaged materials through demolition waste						
Insufficient information on original drawings and other functional information						
Legislative constraints						
Unanticipated cost overruns and financial constraints						
Lack of quality standards and parameters						
Lack of specialized knowledge and multidisciplinary skills from the project team						
Lack of suitable materials to match the existing conditions of the building						
Undamaged materials or elements may subject to degradation						
Inadequate information on requirements of the client						
Introducing changes to existing structure is limited						

Lack of proper communication and coordination between project participants						
Potential future uses may remain uncertain						
Unsafe working conditions						

19. Please specify any other challenges in post fire refurbishment and solutions to those challenges

……..

Thank you very much for the information given.

ANNEXURE III- INTERVIEW GUIDELINE C

Interview Guideline for Experts in Building Performance/ Sustainability

Section I- Details of the Respondent

01. Name (Optional): …….
02. Name of the organisation (Optional): …….
03. Designation: …….
04. Work experience: …….

Section II- Details of the Building Performance Mandates Exercises

Occupancy requirements and comfort related **Building Performance Mandates** (**BPM**) comprise series of five mandates, such as

I. Spatial Performance (**SP**)
II. Thermal Performance (**TP**)
III. Indoor Air Quality (IAQ) Performance (**IAQP**)
IV. Visual Performance (**VP**)
V. Acoustic Performance (**AP**)

I. Spatial Performance (SP)

05. Do you think SP is essential to apparel industry?

Yes	No

5.a. If yes, please describe your answer (how SP affects to building performance and functionality?)

06. Do you think SP is having low priority unless it is enforced by any regulation?

07. What are the impacts of poor consideration of SP to apparel industry?

08. Please point out physiological, psychological, sociological and economic requirements related to SP?

8.a. Physiological requirements

Psychological requirements

Sociological requirements

Economic requirements

09. Please describe the general practice of maintaining SP in the organisation?
10. Do your organisation follow any regulation/ standard/ procedure or guideline regarding SP?
11. How to measure or evaluate SP in the organisation and what are the tools or techniques used?
12. What are the current issues or challenges regarding maintaining SP of the building?
13. Are there any BPM (thermal/ IAQ/ acoustic/ visual) which overlap with SP?
14. ***How fire can affect (impacts/issues) to the SP of the organisation?***
15. What are the solutions to overcome above mentioned post fire challenges or issues?

II. <u>Thermal Performance (TP)</u>

16. Do you think TP is essential to apparel industry?

Yes	No

16.a. If yes, please describe your answer (how TP affects to building performance and functionality?)

17. Do you think TP is having low priority unless it is enforced by any regulation?
18. What are the impacts of poor consideration of TP to apparel industry?
19. Please point out physiological, psychological, sociological and economic requirements of TP?

19.a. Physiological requirements

Psychological requirements

Sociological requirements

Economic requirements

20. Please describe the general practice of maintaining TP in the organisation?

21. Do your organisation follow any regulation/ standard/ procedure or guideline regarding TP?

22. How to measure or evaluate TP in the organisation and what are the tools or techniques used?

23. What are the current issues or challenges regarding maintaining TP of the building?

24. Are there any BPM (spatial/ IAQ/ acoustic/ visual) which overlap with TP?

25. How fire can affect (impacts/ issues) to the TP of the organisation?

26. What are the solutions to overcome above mentioned post fire challenges or issues?

III. Indoor Air Quality Performance (IAQP)

27. Do you think IAQP is essential to apparel industry?

Yes	No

27.a. If yes, please describe your answer (how IAQP affects to building performance and functionality?)

28. Do you think IAQP is having low priority unless it is enforced by any regulation?

29. What are the impacts of poor consideration of IAQP to apparel industry?

30. Please point out physiological, psychological, sociological and economic requirements of IAQP?

30.a. Physiological requirements

Psychological requirements

Sociological requirements

Economic requirements

31. Please describe the general practice of maintaining IAQP in the organisation?

32. Do your organisation follow any regulation/ standard/ procedure or guideline regarding IAQP?

33. How to measure or evaluate IAQP in the organisation and what are the tools or techniques used?

34. What are the current issues or challenges regarding maintaining IAQP of the building?

35. Are there any BPM (thermal/ spatial/ acoustic/ visual) which overlap with IAQP?

36. How fire can affect to the IAQP of the organisation?

37. What are the solutions to overcome above mentioned post fire challenges or issues?

IV. Visual Performance (VP)

38. Do you think VP is essential to apparel industry?

Yes	No

38.a. If yes, please describe your answer (how VP affects to building performance and functionality?)

39. Do you think VP is having low priority unless it is enforced by any regulation?

40. What are the impacts of poor consideration of VP to apparel industry?

41. Please point out physiological, psychological, sociological and economic requirements of VP?

41.a. Physiological requirements

Psychological requirements

Sociological requirements

Economic requirements

42. Please describe the general practice of maintaining VP in the organisation?

43. Do your organisation follow any regulation/ standard/ procedure or guideline regarding VP?

44. How to measure or evaluate VP in the organisation and what are the tools or techniques used?

45. What are the current issues or challenges regarding maintaining VP of the building?

46. Are there any BPM (thermal/ IAQ/ acoustic/ spatial) which overlap with VP?

47. How fire can affect (impact/issues) to the VP of the organisation?

48. What are the solutions to overcome above mentioned post fire challenges or issues?

V. Acoustic Performance (AP)

49. Do you think AP is essential to apparel industry?

Yes	No

49.a. If yes, please describe your answer (how AP affects to building performance and functionality?)

50. Do you think AP is having low priority unless it is enforced by any regulation?

51. What are the impacts of poor consideration of AP to apparel industry?

52. What are the sources of noise/acoustic in the organisation?

53. Please point out physiological, psychological, sociological and economic requirements of AP?

52.a. Physiological requirements

Psychological requirements

Sociological requirements

Economic requirements

54. Please describe the general practice of maintaining AP in the organisation?

55. Do your organisation follow any regulation/ standard/ procedure or guideline regarding AP?

56. How to measure or evaluate AP in the organisation and what are the tools or techniques used?

57. What are the current issues or challenges regarding maintaining AP of the building?

58. Are there any BPM (thermal/ IAQ/ spatial/ visual) which overlap with AP?

59. How fire can affect (impacts/issues) to the AP of the organisation?

60. What are the solutions to overcome above mentioned post fire challenges or issues?

Thank you very much for the information given.

……
……

Dear Sir/Madam,

Research Dissertation – Questionnaire Survey (M.Sc. (by Research)

I am a postgraduate student of University of Moratuwa, reading for Master of Science (by Research). I am conducting a research titled "Post Fire Refurbishment of Apparel Manufacturing Buildings for Enhanced Building Performance". This research is conducted under the supervision of Mr. Mahesh Abeynayake, and Dr Pournima Sridarran, Senior Lecturers at the Department of Building Economics.

I am conducting a questionnaire survey for case studies focussing on apparel manufacturing buildings, which have conducted post-fire refurbishment activity. Below mentioned objectives are intended to be accomplished through these case studies.

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2. Explore the importance of BPMs for refurbishment of fire affected buildings in apparel manufacturing sector

3. Investigate the challenges of managing BPMs and strategies to restore the performance of fire damaged buildings in apparel manufacturing sector

4. Develop a framework to enhance the performance of the post-fire apparel building beyond restoration

The confidentiality of the organization as well as the participants will be maintained throughout the research and the identities of the participants will not be revealed in any document or event relating to this study. I hereby certify that the information collected from this questionnaire survey will be used only for fulfilling the research aim.

Thanking you,

R.M.D.I.M. Rathnayake
Postgraduate Student
Department of Building Economics
University of Moratuwa.
Tel: 071-6935979
Email: dulinirathnayake@gmail.com

ANNEXURE IV- QUESTIONNAIRE SURVEY

Questionnaire Guideline for Professionals who have the Sufficient Knowledge and Experience about Past Fire Incidents

Section I- Details of the Respondent

01. Name (Optional): …….
02. Name of the organisation (Optional): …….
03. Designation: …….
04. Work experience: …….

Section II- Factors contributing to fire incidents/ fire risk

05. Please rate the below listed factors which are affected to building fire incidents. Please indicate your level of agreement regarding below factors to apparel building fires by marking one of the five alternatives.

1	**2**	**3**	**4**	**5**
Strongly Disagree	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Strongly Agree**

	1	2	3	4	5	Solutions
Building designing errors						
Integration errors of building design features and fire safety system						
Large number of horizontal/ vertical continuous openings						
Lack of usage in fire resistant materials						
Errors in fire detection system						
Errors in fire protection system						
Building features/ materials which						

contributed to the speed fire development and fire spread						
Ventilation condition						
Old and wooded building structures						
Improper identifications for fire door, fireman's elevator						
Lift shafts which its doors removed or opened due to refurbishment						
Availability of garbage, papers, and wasted materials which support to fire spread						
Welding work with electrical sparks						
Not involving the building for its' original design function						
Lack of quick response of fire brigade						
Poor equipped fire brigade						
Lack of staff in firefighting service organizations						
Locations of firefighting services in Sri Lanka						
Careless smoking (construction workers are flipped away their cigarette while there are working)						
Sloppy maintenance on electrical tools						
Faulty wiring						
Compatible errors of architectural features and fire regulations						
Differences between considerations in						

policies and findings of actual fire incidents						
Architects' low considerations in fire safety						

06. Please specify any other factors which can affect to Apparel building fire incidents

……..

Thank you very much for the information given.